Condensation Control

in dwelling construction

HOUSING AND HOME FINANCE AGENCY

WASHINGTON, D. C.

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by Forest Products Laboratory, Forest Service
U. S. Department of Agriculture
in collaboration with the
Division of Standardized Building Codes and Materials
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FOREWORD

Economic conditions and material shortages have increased the tendency to construct tight, insulated dwellings of modest size which favor the development of relatively high humidities within the structure and are more subject to condensation problems than older, larger buildings. Methods of controlling condensation have thus become extremely important to both the builder and the home buyer.

This publication shows how to control condensation by means of vapor barriers and proper ventilation. Since thermal insulation and vapor barriers are sometimes combined in house construction, good practices in using insulation are also included.

The methods illustrated in this booklet are based on studies by the Forest Products Laboratory and the Housing and Home Finance Agency and on observations made over many years of buildings involved in moisture problems.

It is hoped that this publication will assist owners, architects, builders, and craftsmen in properly installing vapor barriers, ventilation, and thermal insulation in dwelling construction.

Raymond M. Foley,
Administrator,
Housing and Home Finance Agency.

ACKNOWLEDGMENT

This publication has been prepared by the Forest Products Laboratory, Forest Service, United States Department of Agriculture, in collaboration with the technical staff of the Housing and Home Finance Agency, particularly L. G. Haeger, Director, Division of Standardized Building Codes and Materials, Ralph R. Britton, Chief, Structural Engineering Section, and Laurence Shuman, Chief, Mechanical Engineering Section. The information contained in this publication is based to a large extent on research at the Forest Products Laboratory by Messrs. L. V. Teesdale, Engineer, F. L. Browne, Chemist, and M. E. Dunlap, Engineer, and on observations, engineering studies, and allied studies of building performance conducted by the Laboratory during the past 30 years. The text and details were prepared by M. E. Dunlap, and the illustrations were drawn by J. C. Killebrew of the Forest Products Laboratory. Helpful criticism was made by R. K. Thulman, Chief, Mechanical Engineering Staff, Federal Housing Administration, J. B. Corridon, Director, Plants and Structures Branch, Public Housing Administration, R. F. Luxford, Engineer, Forest Products Laboratory, and by representatives of the insulation, paper, and paint industries. In the development of this publication, particular efforts were made to secure the experience and thinking of representatives of industry, universities, and other Government agencies well known for their study of condensation and its control. More than forty such representatives attended a special conference set up for this purpose by the HHFA, and contributed pertinent suggestions and comments based upon their experience and research. The interest expressed in this work and the data thus obtained were of considerable assistance in the preparation of this publication.

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CONDENSATION CONTROL IN DWELLINGS

INTRODUCTION

Purpose and Scope

This publication presents recommended methods of condensation control by the use of vapor barriers and ventilation in existing and new construction so that those planning houses or those engaged in actual building operations will have a reliable guide based on engineering tests and practical experience. The condensation controls recommended here are applicable to small house construction. Details for the proper installation of vapor barriers, ventilation, and thermal insulation are presented. Since there is a great variety of materials available that may be effectively used in effecting condensation control, it is obviously impossible to show all of them. This publication illustrates the use of only typical materials. Because some materials are shown in particular arrangements of parts does not imply that other materials of equal quality and properties may not be used as successfully.

Background

Condensation control in dwelling construction is now an important consideration in small home construction. A few years ago little or no attention was given to condensation in dwellings nor was there much necessity for doing so since it either did not occur or was of such small extent that it was not a serious problem. Difficulties as a result of lack of condensation control, such as paint peeling and wood decay, have increased in recent years resulting in higher maintenance costs than would ordinarily have been incurred. There are several other conditions arising from lack of knowledge of condensation control that have also affected the building industry and intensified the problem. Many heretofore little understood troubles are now identified with lack of sound condensation control practices.

High prices, the scarcity of building materials, and other economic conditions of today favor the building of small compact houses. Improvements in the machining of wood parts, new materials, and the use of weather strips and storm windows now make both new and old houses tighter than formerly by restricting air leakage or infiltration. Humidifiers, when used indiscriminately, sometimes add greatly

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to the condensation problem, especially during extremely cold weather. Thermal insulation is also used to a greater extent than formerly and as a consequence, outside wall surfacing materials (sheathing and siding) are somewhat colder than those of uninsulated construction. The conditions thus produced are more favorable to moisture accumulations. The use of thermal insulation, however, is not, as is often assumed, the only factor contributing to condensation nor does it attract moisture. For fuel savings, added physical comfort, and less condensation on exposed room surfaces of walls, floors, ceilings, or roofs, insulation is recommended. It must, however, be properly installed with whatever collateral materials or other means that are necessary to prevent the possibility of condensation trouble.

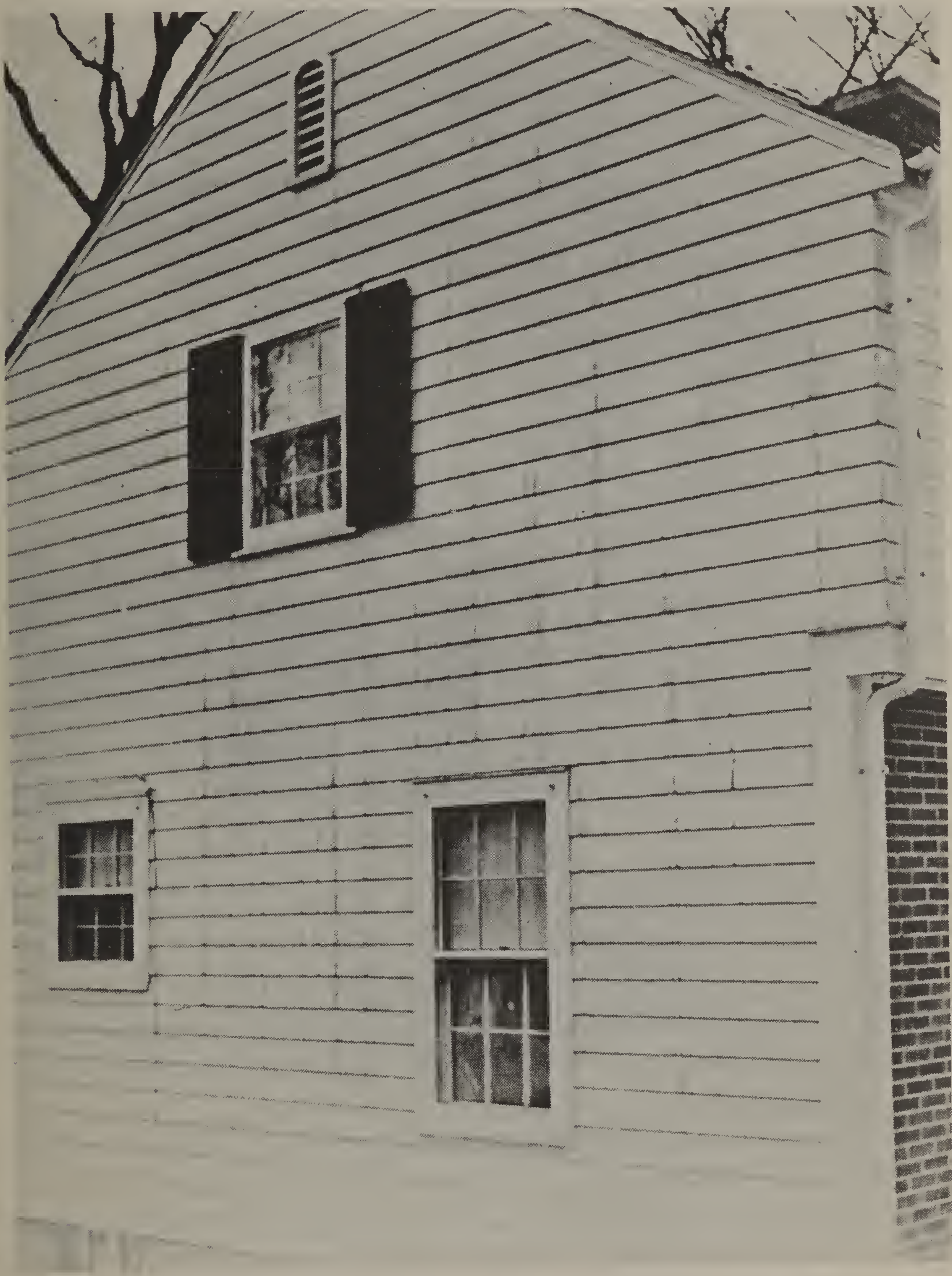
People of today also make more extensive use of water and of appliances discharging water vapor into the living space than in the past, thus making condensation control more essential. People are also inclined nowadays to omit basements in low-cost construction, and often leave an enclosed crawl space below the building. This crawl space may often be damp and thus contribute large quantities of water vapor which due to stack action, may find its way up into walls, attics, and living areas.

The condensation problem in dwellings was first recognized at the Forest Products Laboratory in 1923 during a survey of dwellings on which early paint failure had occurred (*4*).[1] Several agencies have since devoted considerable study to the conditions producing condensation and to the development of construction systems that avoid the penetration of water vapor into walls, attics, or other building parts. Major contributions to this field have been made by the University of Minnesota (*15*, *16*, *17*, *18*), Pennsylvania State College (*14*), Purdue University (*1*, *13*), University of Illinois (*12*, *15*), National Bureau of Standards (*24*), Housing and Home Finance Agency (*2*, *3*, *10*, *11*, *14*, *19*, *20*) and its constituents—Public Housing Administration, Federal Housing Administration (*7*), and the Forest Products Laboratory (*11*, *12*, *21*, *22*, *23*). The Bureau of Plant Industry, Soils, and Agricultural Engineering, (*6*, *8*) United States Department of Agriculture has made important contributions to the control of water vapor in crawl spaces by ventilation and soil covers in an effort to reduce decay damage. The work of these institutions forms a large backlog of information on the condensation problem.

Another source of information is the survey of wartime housing made by the Forest Products Laboratory, National Housing Agency, and other governmental agencies shortly after the end of World War II. The buildings examined were constructed in a variety of ways and located in widely different climates.

[1] Italic numbers in parentheses refer to literature cited at end of this report.

One of the most common and widespread types of damage for which condensation is often responsible is in exterior painting. Condensed water vapor often collects behind the siding of a building in the form of free water or ice. This excess moisture may absorb extractives from the wood and result in stains as it runs out over the surface of the siding (fig. 1). In some cases the condensate thoroughly soaks the siding causing paint blisters and early paint peeling (fig. 2). If moist conditions prevail for a long enough time decay may also result.



PHOTOGRAPH BY FOREST PRODUCTS LABORATORY, U. S. D. A.

FIGURE 1.—Stains on a painted wall produced from condensation collected behind the siding and upon melting carrying wood extractives over the exterior surface. The building, which is at Madison, Wis., in zone I, had fiberboard sheathing and no vapor barrier.

Another type of condensation damage may occur in houses having unventilated flat roofs. Figure 3 shows the damage in a house of this type in which water vapor passed through the ceiling and condensed on the roof sheathing from which it dripped back to the ceiling causing the plaster to crack. No ventilation was provided for the flat roof nor was a vapor barrier used in the house shown in figure 3.

Figure 4 shows a house with pitched roof in which water vapor entering the attic space from the occupied area condensed near the eaves of the house where the structural parts were colder than over the occupied area of the building. The arrows indicate where decay is

PHOTOGRAPH BY FOREST PRODUCTS LABORATORY, U. S. D. A.

FIGURE 2.—Paint peeling caused by condensation in house without basement on poorly drained land, with insufficient ventilation of crawl space. The building is located in zone II at Chicago, Ill., and was built in 1936. Peeling took place after first winter.

starting. It is believed that if the good practice suggested in this publication had been followed, damage of the kind illustrated would not have occurred.

In basementless houses without crawl space ventilation or soil cover, the outside walls, plate, sills, and adjoining joists exposed in the crawl space of the building are often cooled to temperatures below the dew point in the enclosed space. When this happens water often condenses on the surfaces in sufficient quantity to produce conditions favorable to decay (*6*). Examples of this kind are shown in figure 5. The sill at the right is made up of three planks 2 by 12 inches in size spiked together and extending along the outside of the building, so that con-

densation can easily get down between them. The condensation on the joists is greater near the outside of the building and becomes less and less toward the center of the house. Warmth from the heated space above kept the lighter colored sections of the joists free of condensation.

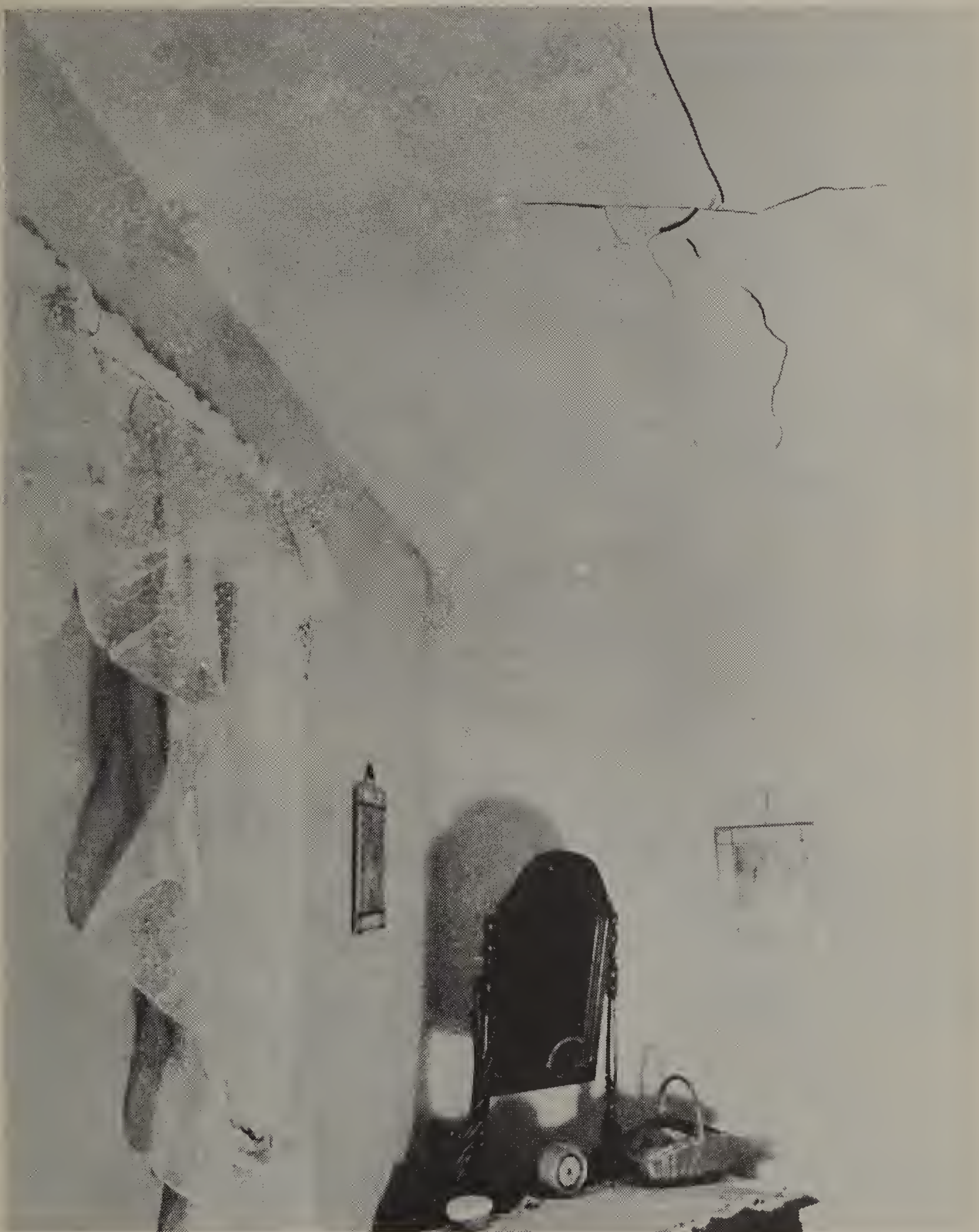


FIGURE 3.—Shows a plaster ceiling under an unventilated flat roof deck where condensation dripped down on the plaster.

PHOTOGRAPH BY FOREST PRODUCTS LABORATORY, U. S. D. A.

FIGURE 4.—Condensation on a gable roof near the eaves is causing decay (arrow) to get started. There was no attic ventilation or a vapor barrier provided. The building was occupied in September and the photograph was taken in December of the same year. The roof was asphalt shingles. The building is located in Madison, Wis., in zone I. The insulation shown is not responsible for the condensation.

PHOTOGRAPH BY DIVISION OF FOREST PATHOLOGY, U. S. D. A.

FIGURE 5.—Condensation drops on floor joists of a basementless house near the outside sill. The sill is made up of three 2- by 12-inch planks spiked together and the condensation can easily get down between them. The building is located in the vicinity of Washington, D. C.

Condensation control in dwellings is often accomplished by the proper use of vapor barriers, ventilation or a combination of both. Vapor barriers (*21*, *22*, *23*) are membranes, aluminum or oil paint films, rubber base paints, metallic sheets, or other materials or coatings that prevent objectionable amounts of water vapor from being absorbed or transmitted through walls, floors, and ceilings. Vapor barriers are no better than their quality nor thoroughness of their installation. They should be selected for quality and should be carefully placed. Ventilation is suitable for reducing water vapor concentration in attics and in unheated crawl spaces below living quarters. In some dwellings it is desirable to provide ventilation for the living quarters in order to lower the relative humidity and thereby reduce condensation hazards.

Added roof protection at the eave line to prevent backing up of melted snow and ice is shown in figures 50 and 51. Trouble from this source is often erroneously blamed on condensation.

Vapor Barriers

Adequate, well-installed vapor barriers are an effective means of preventing troublesome deposits of frost or water in walls and attics of small houses exposed to low temperatures. The vapor barrier should form a tight envelope near the warm side of the building element in which it is installed.

Many materials used as interior surfaces of outside walls, ceilings, and roofs will permit water vapor to pass through them slowly when the relative humidity or vapor pressure is different on opposite sides unless a vapor barrier is provided. Low temperatures of the sheathing, building paper, or siding on the outside of the wall often condense water vapor from the cavities of a frame wall and induce low humidities or vapor pressures. When the relative humidity or vapor pressure within the house at the wall surface is greater than that within the wall, water vapor will migrate in the absence of an effective vapor barrier through the plaster or other finish into the wall cavity and will condense if it comes in contact with surfaces below its dew point. This process may continue throughout the heating season at varying rates depending on conditions in and out of the house.

The water vapor that enters wall cavities is often generated within the living space of the building and may come from a number of sources. It is given off by the occupants through respiration, and by cooking, bathing, washing, and by humidifiers. It may amount to from 5 to 10 pounds of water for ordinary daily activities. Washing

and drying clothing indoors may release about 30 pounds of water.[2] The quantity of water vapor given off will depend on the daily habits of the family occupying the space. Where there are young children and considerable washing, the problem of condensation is likely to be more serious. Measurements and observations taken by the Housing and Home Finance Agency indicate that moisture contribution to a dwelling from a crawl space may be far greater than that resulting from living habits of the people. Such contribution, with improperly vented or untreated crawl spaces may be as high as 100 pounds of water per 24 hours per 1,000 square feet of enclosed crawl space. The water vapor generated within a dwelling is first diffused through the space within the building, thereby increasing the relative humidity. Some of it is absorbed by rugs, fabrics, and other house furnishings, and some is condensed on windows. This water may be removed slowly from the living quarters by the opening of outside doors, by diffusion through walls and ceilings into cavities or attic spaces, by leakage around windows and doors, by way of air supplied to burning fuel in heating equipment vented into chimneys, and by air exhausted by the use of kitchen ventilating fans, etc.

Materials of high vapor resistance may be placed in or on the warm side of exterior walls to retard the movement of water vapor into the wall cavities. Such vapor barriers should be efficient, carefully installed, and make a complete envelope to keep the water vapor from passing into zones where subsequent damage may result.

A good vapor barrier (*21*, *22*, *23*) should permit not more than 1 grain of water vapor to pass through an area 1 foot square in 1 hour when the vapor pressure difference is calculated on the basis of 1 inch of mercury when tested by a dry method. It should have sufficient mechanical strength to permit handling during erection without damage (*11*). It should also retain its vapor resistance qualities for the life of the building or, if a paint film, until it is renewed.

When the vapor barrier is installed it should not have an average vapor transmission rate greater than 1.25 grains per square foot, per hour per inch of mercury differential including joints, fittings around outlet boxes, and the like. Damaged vapor barriers should be replaced or restored.

A number of satisfactory materials or combination of materials are available that restrict the movement of water vapor (*21*, *22*, *23*). These include asphalt impregnated and coated papers having a glossy or bright finish. This feature is important since thin, dull-surfaced papers are not generally so effective as is the glossy finish. Duplex papers composed of two sheets of 30-pound kraft paper with a 60-

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[2] The American Gas Association, in cooperation with the Purdue University Research Station, Lafayette, Ind., expects to release more complete data on all the major sources of water vapor. This work is under the direction of Mr. Eugene D. Milener, Coordinator of Utilization Research, American Gas Association, Cleveland, Ohio.

pound per 3,000 square feet asphalt layer between them; aluminum foil mounted on one or two sides of a paper support, or attached to the plaster base; or aluminum paint, oil paint, or rubber base paint in sufficient coats to result in a smooth glossy finish are types of material that may be expected to give satisfactory service.

Papers used to support insulating materials using narrow strips of asphalt as an adhesive to joint the paper and insulating materials are not usually good vapor barriers and their value for this purpose should be accurately confirmed before purchasing. In fact, this procedure should be applied to any material used as a vapor barrier.

Sheathing Paper or Sheathing

In contrast to the vapor-tight properties of the warm side of a wall, those of the cold side are just the opposite in that a construction capable of losing moisture that might gain entrance to the wall is highly desirable. On the other hand, the exterior surface must also provide protection from the weather; that is, resistance to rain and strong winds. Because of these external conditions it is necessary to keep the outside of a building relatively tight. Paint on the exterior surface helps retard the movement of moisture outward. Sheathing paper, sometimes called breathing paper, between the sheathing and the finish siding has been customarily used to reduce infiltration of cold air and to prevent the penetration of wind-driven rain. In order that as little restriction as possible to the release of moisture be built into a wall, it is recommended that the sheathing paper and the sheathing be of types that will readily transmit water vapor.

A satisfactory sheathing paper or sheathing should be capable of passing 5 or more grains of water vapor per square foot, per hour, per inch of mercury when tested by a dry method and should be resistant to wetting by free water and have satisfactory strength for handling and service.

Ventilation

Ventilation in proper amounts and effectiveness is a recognized means of controlling condensation in buildings. By introducing fresh air into living quarters during the winter, some water vapor is forced out of the building and air containing a low vapor content is introduced. In this way high vapor pressures which are a factor in producing condensation are reduced to a considerable extent. Ventilation is effective in preventing condensation in unheated attics, spaces below flat roofs, and crawl spaces in basementless houses. Although much is yet needed in experience and test data to prove the efficiency and effectiveness of ventilation in the cold cavities of walls to prevent condensation, there are some data indicating favorable results with an upward air movement on the cold side of any in-

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sulation in the cavity. This air movement should have the intake from the outside and should exhaust to the outside at the top of the wall unless provision is made to disperse the moisture added to other spaces above the wall. The burning of fuels for heating tends to increase the amount of fresh air entering a building and thus provides ventilation in the occupied spaces. No special provision is ordinarly made for it to enter since it usually gets in through infiltration or leakage into the building around doors and windows. Where the construction is weather stripped and has tight exteriors, additional openings may be required.

When heavy deposits of condensed water vapor or frost occur on window glass, especially if there are storm windows, ventilation of the living space should be provided.

Moisture released by the soil in a crawl space tends to produce a high relative humidity, especially when the crawl space is enclosed. Under such conditions the exposed surfaces may be subject to condensation with its damaging results. This applies to lumber, insulation, metals and mechanical lines. If the temperature of surfaces near the outside perimeter of the building are lowered sufficiently, free water will condense on them. The increase in moisture content above fiber saturation (if lumber) favors the growth of decay organisms, especially if it persists when wood temperatures are 50° to 80° F.

Attic spaces are sometimes a source of trouble because of condensation on roof boards, shingles, or on long nails extending through the roof into the attic. Where the attic floor is well insulated, adequate ventilation in the attic is a safeguard against such condensation difficulties.

Ventilation in the cold cavities of walls by openings at both top and bottom is considered effective in preventing condensation in the cavity provided they open to the outside. Research to date indicates that 1 inch of opening per running foot of wall at both top and bottom is effective.

During the warmer months of the year a deposit of water or condensation is frequently found on basement walls and floors (*13*, *20*) that are in contact with the soil. Soil temperatures in the northern part of the United States remain low in the summer and at times atmospheric conditions become such that the surface temperature is below the dew or condensing point and water is deposited from the surrounding atmosphere on cold surfaces. This type of water deposit is often confused with or thought to be water seeping through the concrete. In most cases, it does little harm, but where the floor or walls are covered with decorative materials precautions are necessary to prevent damage to them through decay or discoloration.

This type of condensation is often referred to as temporary condensation as it stops when warm air heats the surfaces to a temperature above the dew point.

Heat is transmitted through a wall or other building element by conduction, convection, and radiation. Heat flows from the warm to the cold zones and it may be transmitted by any one or by all three methods. Materials, such as masonry, wood fiberboard, and fibrous materials, all transmit heat by conduction in varying amounts. Air spaces transmit a small amount of heat by conduction, but generally to a greater degree by convection and radiation. For example, where a cavity in a wall exists warm air tends to rise and cold air tends to fall, thus creating circulating currents that carry heat upward on the warm side of the wall and downward along the cool side and in this way heat is transferred by convection from the warm to the cold side. Cavities in a wall are sometimes termed "dead air" spaces. Actually, air is never still or "dead" where a difference in temperature exists between opposite sides of a wall and consequently their value is sometimes greatly overestimated. Convection currents also play an important part in transferring heat as they flow over the surfaces of walls. Rapidly moving air removes greater quantities of heat than do slower currents. With a wind of 15 miles per hour, for example, the film or surface coefficients will be four times as great as it would be with still air on the cold side of the wall.

The third method of heat transmission is by radiation, which means that heat is transmitted from a warm to a cold body by wave motion through space. Thus heat is enabled to move through wall cavities and from the outside surface of a wall to cooler objects even at some distance from it. Heat is received from the sun in this manner.

In the winter the function of thermal insulation is to reduce the rate of flow of heat from a heated building and thereby reduce the amount of fuel that would otherwise be required, make possible the use of heating equipment of smaller capacity, and produce more comfortable living quarters. When thermal insulation of suitable quality is used the inside wall surfaces are warmer and produce more comfortable living conditions than uninsulated walls. Likewise, during the summer thermal insulation slows the movement of heat into interior areas, thus providing greater comfort.

A wall, floor, or ceiling may be made up of a number of structural elements, and all parts including air or unfilled spaces contribute more or less to the resistance to heat movement and should be considered in selecting a material to improve the heat transmission characteristics of a wall. It is not enough to say that a wall is insulated because it contains some material sold for insulation; it is the quality and amount of insulation of the assembly that counts.

Manufacturers of insulating materials can supply printed figures giving the coefficients ("U" values) for heat transmission for various types of building assemblies so that the purchaser can select his

materials for insulation and arrange them to the best advantage. Other sources of information will be found in literature citations (*1*, *5*, *7*, *8*, *9*, *12*, *16*, *18*, *19*, *20*, *23*). A map showing suggested thermal insulation design values by zones is given in the appendix together with a table of "U" values that will produce acceptable and preferred floor temperatures. The bulk of the materials sold as thermal insulation gain their effectiveness because they have a low density or have reflective properties. Because they represent heat losses, low "U" values indicate better thermal insulation qualities.

There are a number of loose fill materials of granular fibrous type that make up a relatively low density mass and make good insulating materials. Some materials of this kind are granulated cork (not often used in house insulation), vermiculite or expanded mica, nodulated rock, slag, or glass wool, shredded redwood bark, powdered gypsum, dry sawdust and shavings, and wood base and other organic fibers.

Expansible fiber insulation is supplied in small rolls and they are extended or elongated when put into service. It does not have an integral vapor barrier, but a continuous separately applied type is recommended by the manufacturers. The insulation is made wide enough for tacking along the edges to hold it permanently in place. It is supplied in thicknesses of ½, 1, and 2 inches.

Paper-covered blanket insulation is supplied in rolls usually with flanges for attachment to framing members. It may be had in thicknesses of ½, 1, 2, and 3 inches. It is usually furnished with vapor barriers attached.

Insulating board, also known as fiberboard, is supplied in ½- and 25/32-inch thicknesses. Because of its moderate density it functions as an insulating material. Sheets 2 by 8 feet or larger are supplied for interior dry-wall finish and exterior sheathing. Smaller sheets are used for plaster base and may be obtained with coatings which serve as vapor barriers.

Batts are designed to fit between studs or joists and are made both 2 and 3 inches thick.

Reflective insulation is supplied in several forms. Aluminum reflective insulation is frequently made in the form of foil or special coatings supported on paper and may be single- or double-faced. Aluminum foil is also supplied attached to gypsum board plaster base and in this form serves as a vapor barrier. It is important that joints be made tight when relied on as a vapor barrier. Sheet steel is also used for this purpose. An air space adjacent to each reflective surface is required for effective insulation. A cellular type reflective insulation is also available.

Condensation Control Zones

For purpose of setting forth a sound intelligent approach to this problem and to facilitate reference, a map showing condensation design zones has been prepared as figure 6. It divides the United States into three condensation control areas, as illustrated. These zones are considered to be areas of approximately equal over-all outside temperature and exposure duration as they relate to potential winter or prolonged condensation trouble.

Zone I, the most severe, roughly includes those areas generally considered to have design temperature of −20° F. and colder. Zone II roughly includes the —10° F. design temperature areas, and zone III takes in areas of zero and warmer.

CONDENSATION ZONES

FIGURE 6.—Condensation zones.—Zone I roughly includes the areas with design temperatures —20° F. and colder; zone II 0° to —10° F.; and zone III areas warmer than 0° F.

Sizes of Ventilators

There has been some confusion in the past on amounts of ventilation area intended when terms such as "area," "free area," "gross area," "net area," and just plain "ventilation" are used. Little has been understood or appreciated by architects and builders on the effect of air movement restriction such as (1) by louvers, (2) by fine mesh insect screen, and (3) by grills containing relatively small holes.

For specification purposes and as used in the following discussion of amounts of ventilation recommended, the values given will be the "net amount of ventilation." The "net area" is the approximate unobstructed, clear or free opening through which air may move in or out

of the enclosed space. The "gross area" is the total area of the ventilator, louver, or grill and includes the net area as well as the solid material obstructing the flow of air. The relation between "net" and "gross" area for calculation purposes may be considered to be those set forth below:

1. When the ventilation opening is obstructed by only ¼-inch mesh hardware cloth, the gross area may be equal to the specified net area.
2. When the ventilation opening is obstructed only by screening with 8 mesh to the inch, the gross area provided should be one and one-fourth times the specified net area.
3. When the ventilation opening is obstructed only by insect screen with 16 mesh to the inch, the gross area provided should be two times the specified net area.
4. When the ventilation opening is obstructed by louvers and hardware cloth having ¼-inch mesh, the gross area should be two times the specified net area.
5. When the ventilation opening is obstructed by both louvers and screening with 8 mesh to the inch, the gross area should be two and one-fourth times the specified net area.
6. When the ventilation opening is obstructed by both louvers and insect screen with 16 mesh to the inch, the gross area should be three times the specified net area.
7. For other combinations of screen and louvers or grills, gross sizes should be based on the above recommendations which indicate the magnitude of the resistance to free air movement of various obstructions in a ventilation opening.

Ventilation should not contain openings larger than those listed below:

	Inch
Crawl spaces	¼
Attic or loft spaces	⅛

Crawl Spaces

Condensation control by ventilation

Where there is no other means of effective condensation control, and in the absence of a definite determination that the soil is not a large supplier of moisture to the crawl space, the total net amount of ventilation should be 2 square feet per 100 lineal feet of building perimeter plus one-third of 1 percent of the crawl space ground area. For convenience in reference, the amount thus obtained is referred to as that required by the two plus one-third formula.

Good practice in condensation control in crawl spaces includes the following:

1. At least four ventilating openings, with one near each corner of the building, should be used.
2. The openings should be placed as high as possible in the walls of the crawl spaces.
3. When the ventilation thus provided is the only means of condensation control, such ventilation should not be closed at any time during the year.
4. When such ventilation serves as condensation control, low temperatures under the first floor may be expected and insulation may be required in the floor and around exposed mechanical lines for comfort and to prevent deterioration.

Condensation control by ground cover

Since in many northern areas it is not practical to allow a free sweep of cold air below a dwelling floor, an alternate method of condensation control in crawl spaces has been developed. This consists of stopping the moisture from the ground from entering the air in the confined space by covering the ground with a vapor-resistant durable material. A good water-proofed concrete slab or heavy roll roofing has been shown to be effective. A roll roofing; either mineral surfaced or plain, weighing at least 55 pounds per 100 square feet, laid with 2-inch lapped joints over a rough-graded surface, may be expected to serve satisfactorily for many years. Generally the lap joints need no cementing material.

Where a good cover is applied over the entire surface of the ground in the crawl space, very little ventilation is needed. However, to be on the safe side, it is recommended that at least 10 percent of the ventilation indicated by the two plus one-third formula be provided.

Other crawl space recommendations

In crawl space construction the following good practice requirements for taking care of matters other than the condensation problem under discussion are recommended:

1. Adequate headroom for the purpose of maintenance of equipment.
2. Proper slope of outside grading away from the building.
3. Possible drains in the crawl space if the ground level is below outside grade and of a soil composition not allowing seepage of water through it.
4. Full 18-inch clearance between ground and bottoms of wood framing or other material subject to attack by termites.
5. Ready access to all parts of crawl spaces for inspection against deterioration and termites.

Walls

It is recommended that in all cases where the walls contain materials adversely affected by moisture or by freezing in the presence of moisture, an effective vapor barrier be provided on the warm side of the wall under the following conditions:

1. When the wall is insulated to a degree that the over-all "U" value is numerically lower than 0.25 B. t. u. per hour, per square foot, per degree Fahrenheit. This applies to dwelling construction erected in any of the three condensation zones.
2. When the wall has a siding, or a sheathing, or a sheathing paper or any other material on the cold side of the wall which material, as applied, has a water vapor permeability of less than 5 grains per hour, per square foot, per 1 inch of mercury pressure differential, and the dwelling is located in condensation zones I or II.

Note.—Under either of the two conditions set forth above, a vapor barrier is recommended in the walls. The question immediately arises—does this recommendation apply to all dwellings regardless of size? A positive answer is difficult to give since living habits of people, moisture-making equipment within the dwelling, and the density of occupancy vary greatly in houses of equal size.

A definition of a small tight house is given in the Glossary of terms. In the case of the small tight house, or one approaching it, the vapor barrier in the walls is considered a definite necessity to prevent condensation in the wall with its resulting damage.

In the case of a larger house, this necessity for a vapor barrier is not as urgent. However, pending further research and the development of technical data, the vapor barrier is highly recommended because of its value in preventing condensation within the wall with its adverse effect on painted wood sidings and other materials.

Lofts or Attics

In considering good practice for treatment of lofts, attics, and other spaces above the normal living quarters of a dwelling it is recognized that, in many instances, ventilation has been counted on in the past for condensation control. It is correct to assume that ventilation will still perform satisfactorily under certain conditions. It must, however, be effective as installed and this requires (1) an adequate amount, (2) proper location, (3) continuous operation, and (4) circulation through all spaces to be ventilated.

An established amount of ventilation so placed that it operates efficiently may well serve satisfactorily when the ceiling is not insulated and the roofing or gable ends have the ability to breath (allow water vapor to readily pass on through to the exterior).

With insulation added or with built-up, metal, composition or other tight roofs, or a combination of them, this ventilation in the same

amount and location may not be nearly as effective. Technical data gathered over the past several years prove that under the conditions just cited the resulting high relative humidities and low surface temperatures are major contributing factors leading to trouble.

As a practical guide in setting forth recommended good practice for the usual conditions encountered in dwelling construction, table 1 has been prepared.

In the case of flat roofs, ventilation at the eave lines only is not considered sufficiently effective in itself. Vapor barriers are therefore definitely recommended in addition to ventilation in all zones. Adverse experience with this type of roof substantiates the technical analysis of the problem.

In the case of roof construction where the ventilation is advantageously placed high in the gable ends, vapor barriers are not indicated as a definite recommendation to avert trouble except in the severe condensation zone I. The omission of the barrier as a positive recommendation in condensation zones II and III results from a cost viewpoint pending receipt of evidence of trouble when other good practice recommendations of this chapter have been employed.

Net amounts of ventilation area are given in fractions, thus: 1/300 or 1/600. They apply to the area of the building or part thereof at the eave line.

TABLE 1.—*Recommended good practice—loft and attic ventilation* [1]

Type of roof and occupancy	Condensation zone		
	I	II	III
(a) *Flat roof.* Slope less than 3 inches in 12 inches. No occupancy contemplated.	Total net area of ventilation should be 1/300 [2] distributed uniformly at the eaves *plus* a vapor barrier in the top story ceiling. Free circulation must be provided through all spaces.	Same as for zone I.	Same as for zone I.
(b) *Gable roof.* Slope over 3 inches in 12 inches. No occupancy contemplated.	Total net area of at least 2 louvers on opposite sides located near the ridge to be 1/300 [2] *plus* a vapor barrier in the top story ceiling.	Same ventilation as for zone I. A vapor barrier is not considered necessary.	Same as for zone II.
(c) *Hip roof.* No occupancy contemplated.	Total net area of ventilation should be 1/300 [2] with 1/600 [2] distributed uniformly at the eaves *and* 1/600 [2] located at the ridge with all spaces interconnected. A vapor barrier should also be used in the top story ceiling.	Same ventilation as for zone I. A vapor barrier is not considered necessary.	Same as for zone II.
(d) *Gable or hip roof.* With occupancy contemplated.	Total net area of ventilation should be 1/360 [2] with 1/600 [2] distributed uniformly at the eaves *and* 1/600 [2] located at the ridge with all spaces interconnected. A vapor barrier should also be used on the warm side of the top full story ceiling, the dwarf walls, the sloping part of the roof, and the attic story ceiling.	Same as for zone I.	Same as for zone I except that a vapor barrier is not considered necessary if insulation is omitted.

[1] It is recognized that in many areas increased ventilation may be desirable for summer comfort.
[2] Refers to area enclosed within the building lines at the eave level.

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CONDENSATION CONTROL DETAILS

To supplement the good practice recommendations set forth in the preceding section, a series of drawings (figs. 7–56) have been prepared. Each drawing represents one construction detail and with the accompanying description shows the proper arrangement of vapor barriers, ventilation openings, and other collateral materials in the particular assembly illustrated. The reader should always keep in mind the title of the figure and the purpose intended. It is impossible in each drawing to show in detail all materials and items not pertinent to the point being considered.

ONE-STORY, FLAT-ROOF HOUSE

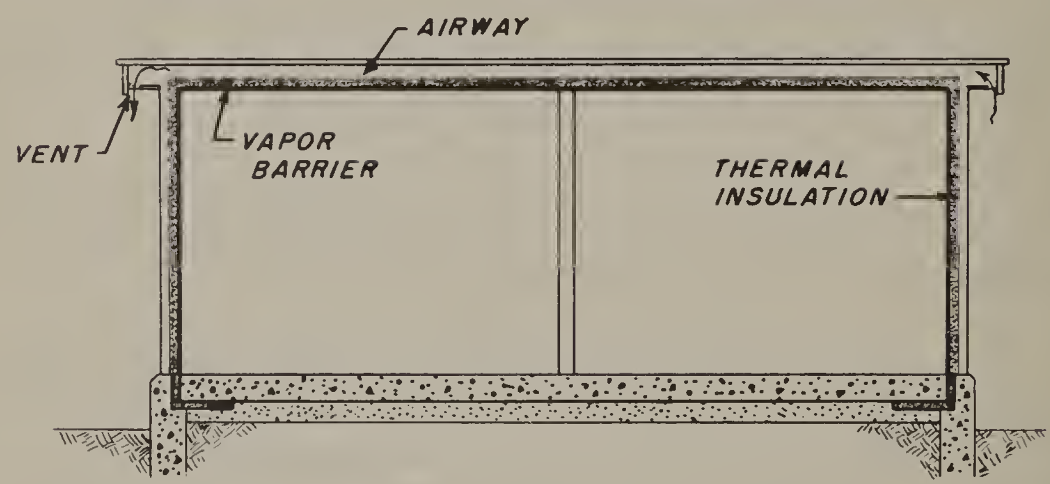

FIGURE 7.—*One-story, flat-roof house.* Condensation control is obtained by means of a vapor barrier in the walls in condensation zones I and II and in the ceilings of zones I, II, and III. Ventilation should be provided between the thermal insulation and the roof deck in all zones. Thermal insulation should be used in zones I and II in the walls, and in the ceilings in zones I, II, and III. It should be applied also at the junction of the footing wall and the concrete floor slab to break up the continuity of the concrete.

BASEMENTLESS HOUSE, ONE-STORY

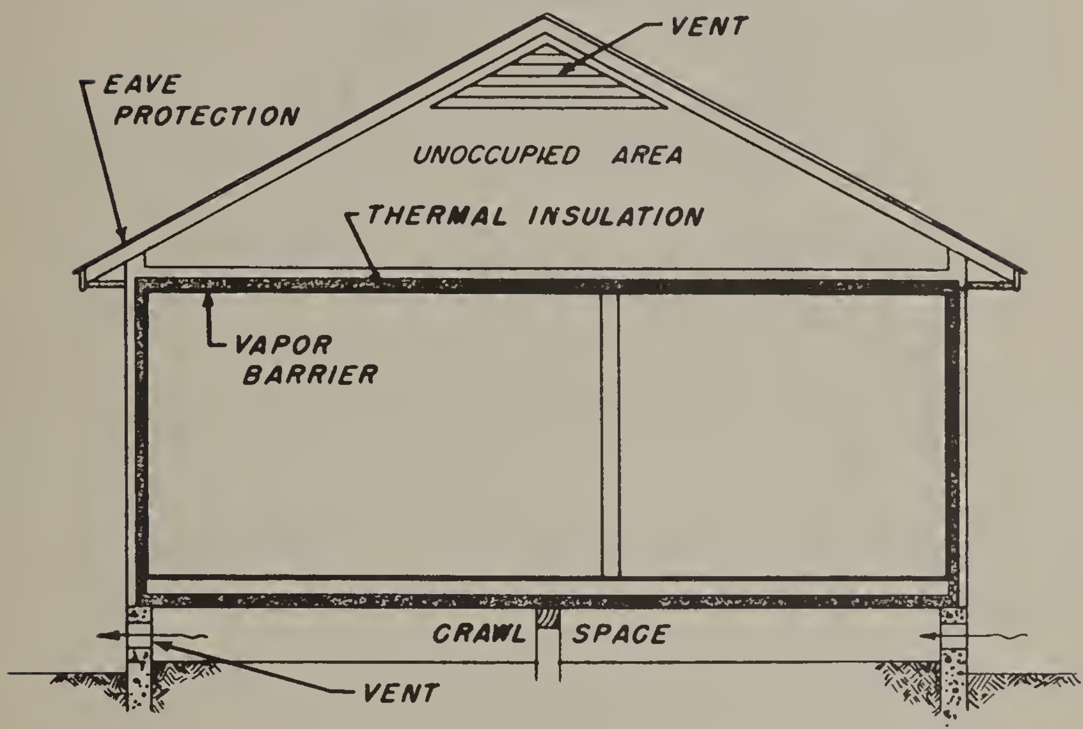

FIGURE 8.—*Basementless house, one-story.* Condensation control is effected by the use of a vapor barrier near the warm surface of outside walls and ceilings and floors and by ventilation of the attic and crawl spaces. The vapor barrier in the floor below the thermal insulation protects the finish floor from dampness that might exist in the crawl space and in this case the barrier should be placed below the finish floor. Vapor barriers should be provided in condensation zone I for ceilings, walls, and floors; in zone II for walls and floors; and in zone III for floors. Ventilation should be provided in the side walls of the crawl space for all three zones. Thermal insulation should be included in all walls, ceilings, and floors of condensation zones I and II. Eave protection in the form of one course of roll roofing is recommended for zones I and II where wood or composition shingles are used. In zones I and II ice dams may form over the eaves causing water to back between the shingles and into the building.

ONE-AND-ONE-HALF-STORY HOUSE WITH BASEMENT

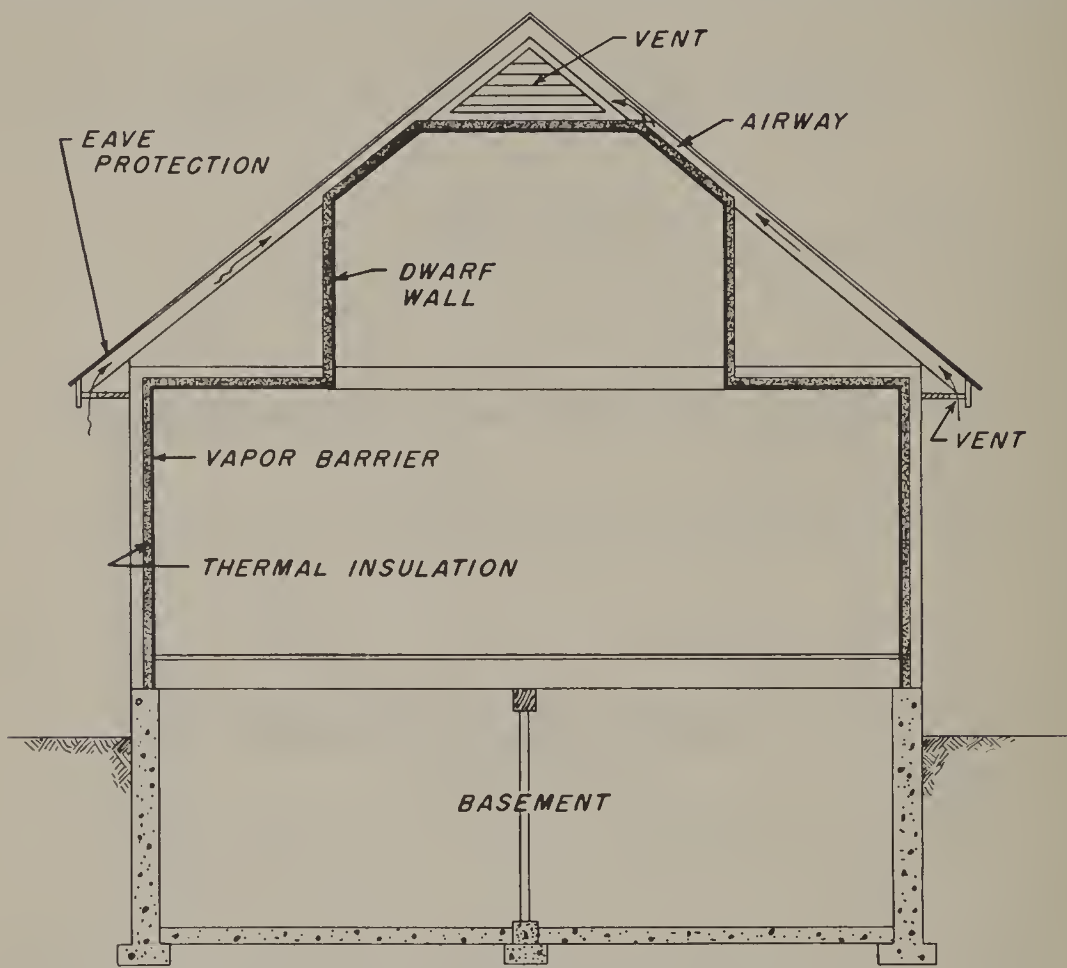

FIGURE 9.—*One-and-one-half-story house with basement.* Condensation control is supplied by a vapor barrier which should follow the inside line of the insulation and should effectively shut off the space between the joists below the dwarf wall or be continued across the ceiling of the first story and by ventilation. Vapor barriers should be provided in condensation zones I and II for ceilings and walls, and in zone III for ceilings if insulated. Ventilation should be provided in all three zones in the gable as well as supplementary vents running continuously under the eaves to remove water vapor from the unheated spaces. Thermal insulation should be provided to form an envelope around the heated living quarters above the basement for zones I and II. It is important that an airway be provided for the full length of the rafter. Eave protection is recommended in zones I and II in the form of one course of roll roofing below the shingles and over the eaves. (See figs. 50 and 51.) In zones I and II ice dams may form causing water to back under the shingles and into the house.

TWO-STORY HOUSE WITH BASEMENT

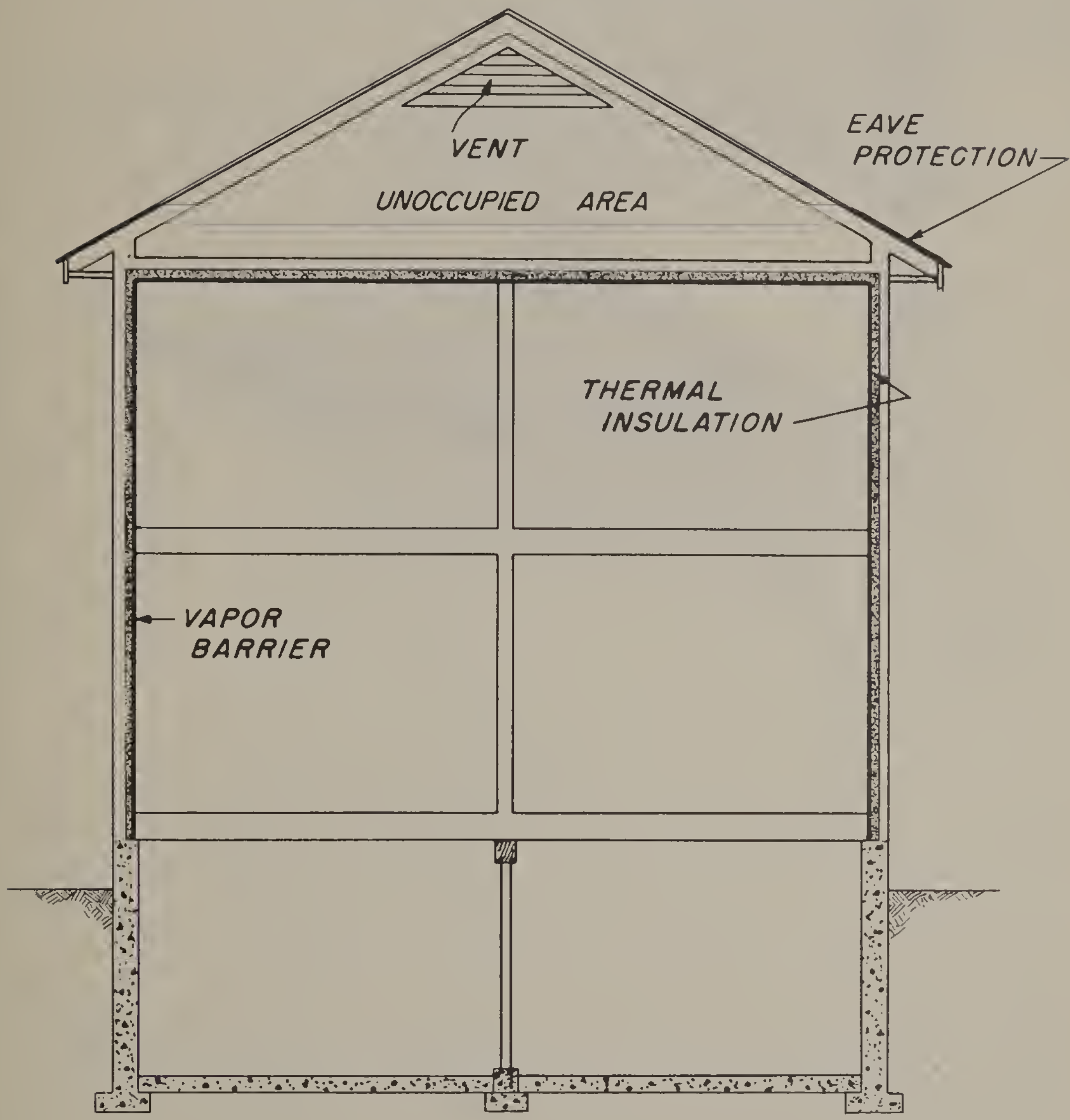

FIGURE 10.—*Two-story house with basement.* Condensation control is obtained by means of a vapor barrier and ventilation. The vapor barrier should follow the inside line of the insulation and should effectively close the space between first- and second-floor joists. Vapor barriers should be provided in condensation zone I for ceilings and walls, and in zone II for walls. Ventilation for the attic space should be provided in all three zones. Thermal insulation should be applied to form an envelope around the heated living quarters above the basement in zones I and II. Eave protection in the form of roll roofing is recommended below the shingles and over the eaves in zones I and II. (See figs. 50 and 51.) In zones I and II ice dams sometimes form over the eaves causing water from melting snow or rain to back into the house.

BASEMENTLESS HOUSE, CONCRETE SLAB FLOOR

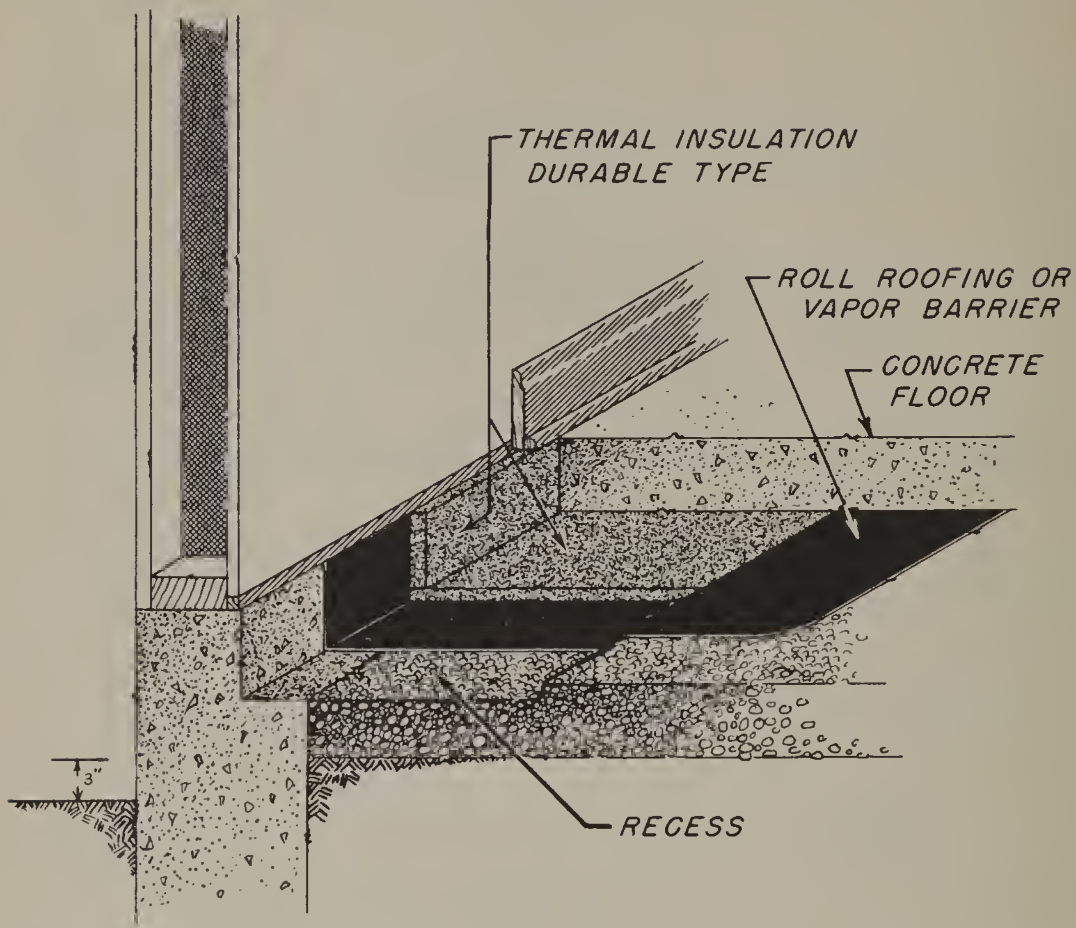

FIGURE 11.—*Basementless house, concrete slab floor.* When concrete floors are laid directly on the soil, condensation may occur on the concrete floor in either winter or summer. Condensation in the winter will occur when temperatures are low out-of-doors and the temperature of the surface of the concrete along the walls is also low because of the relatively high thermal conductivity of the concrete wall and slab. When the temperature of the concrete slab falls below the dew point of the water vapor in the adjacent atmosphere, condensation will occur. Condensation control is had by breaking the continuity of the concrete and permitting the floor to rise to a higher temperature. Thermal insulation having at least a resistance value (R) of 2.0 should be provided about 1 foot 6 inches wide around the perimeter of the concrete slab and should extend up over the edge of the slab. The insulation should be of a waterproof type or thoroughly covered with a heavy coating of asphalt. A recess in the concrete along the wall and in the gravel fill should be provided in which the insulation can be laid. Heavy roll roofing or durable vapor-barrier type paper should be spread over the gravel before laying the finished concrete floor in order to prevent seepage of water from the soil. Floors laid directly on the soil are affected by soil temperatures that are normally lower than average air temperatures in summer. This tends to favor summer condensation, especially when a building is new and before soil temperatures below the building are materially raised by the previous heating season. Unfortunately there is no construction detail that will materially assist in controlling summer condensation. The use of a low density concrete with vermiculite as part of the aggregate or the use of thermal insulation below the floor would reduce the possibility of such difficulties.

BASEMENTLESS HOUSE, CRAWL-SPACE VENTILATION

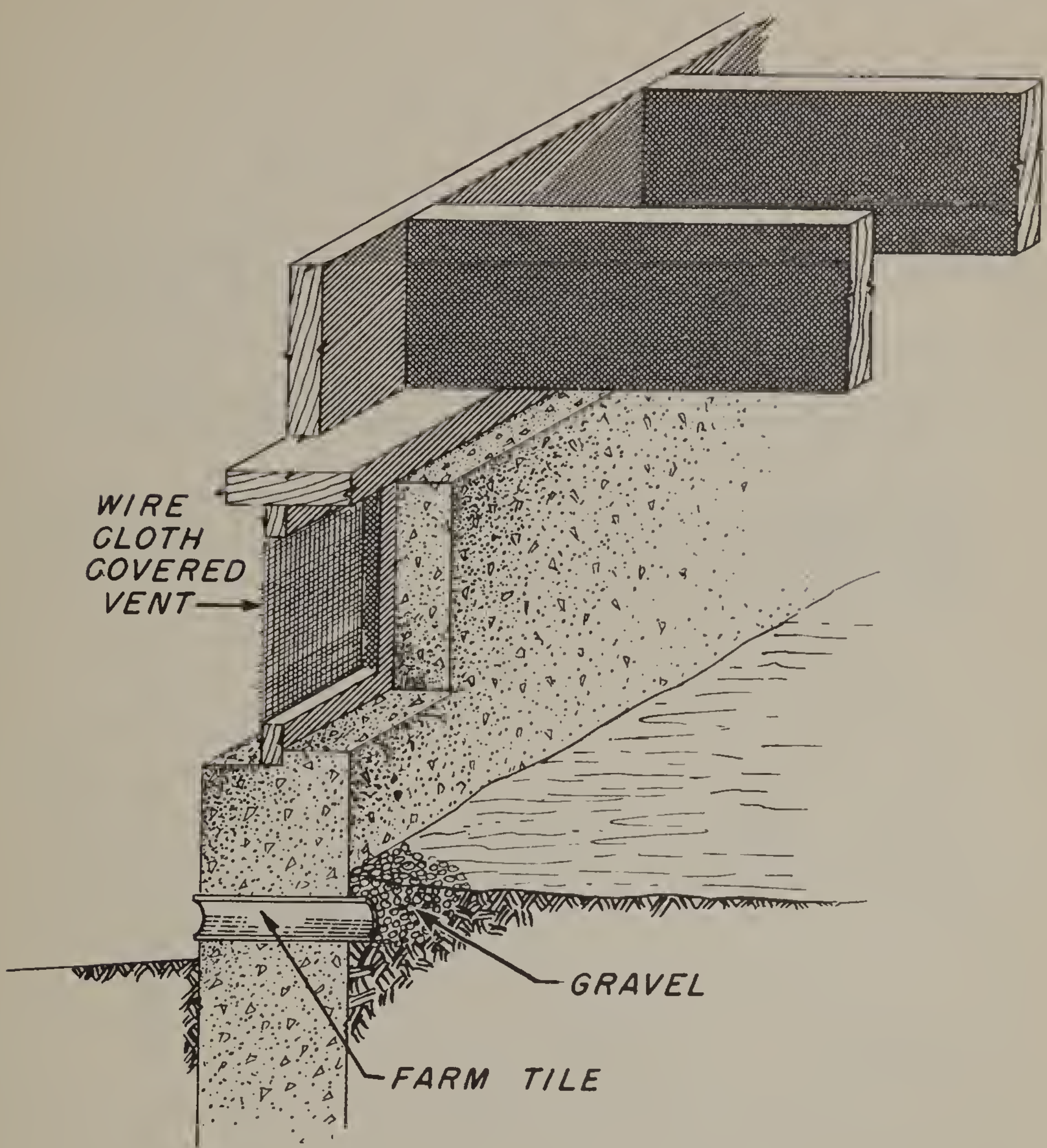

FIGURE 12.—*Basementless house, crawl-space ventilation.* The shallow space between the soil and floor joists in basementless houses in some cases may become very damp because of evaporation from the soil surface. Under such conditions a high moisture content will occur in adjacent woodwork and water will condense on sills, joists, and other parts near the outside wall when outside temperatures drop rapidly. Condensation control in this detail depends on ventilation. At least 4 vents should be used and they should preferably be placed near the corners of the building. The net openings required for a given house may be computed as indicated in the section entitled "Good practice recommendations." The openings should be placed as high as possible since there is likely to be less obstruction to interfere with air movement. In northern climates the floor of the living quarters should be adequately insulated so that the ventilators can be left open all the year. If the building is located on a sloping site, drain tiles on the low side are suggested to permit water to drain from the crawl space. Stones piled over the tile opening will prevent the entrance of small animals but will permit water to escape. Plumbing pipes, of course, should be insulated.

BASEMENTLESS HOUSE, CRAWL-SPACE VENTILATION

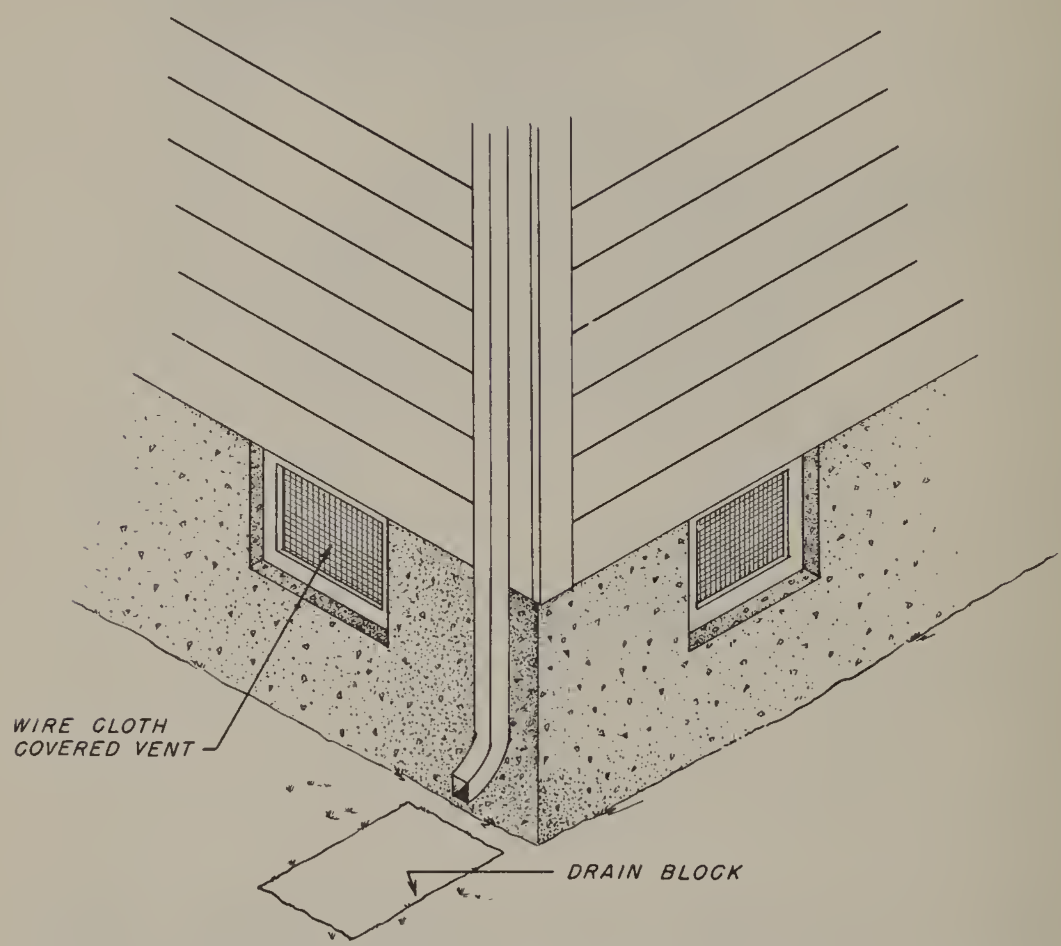

FIGURE 13.—*Basementless house, crawl-space ventilation.* Condensation control indicated in figure 12 is further illustrated by screened ventilators in the foundation wall. Two vents are indicated but in small houses one vent per corner would probably meet the requirements in a satisfactory way. A splash block and a gentle slope away from the building will tend to minimize the possibility of water getting under the building. The use of an underground drain would be preferable to surface drainage.

REPRESENTATIVE TYPES OF VENTILATORS

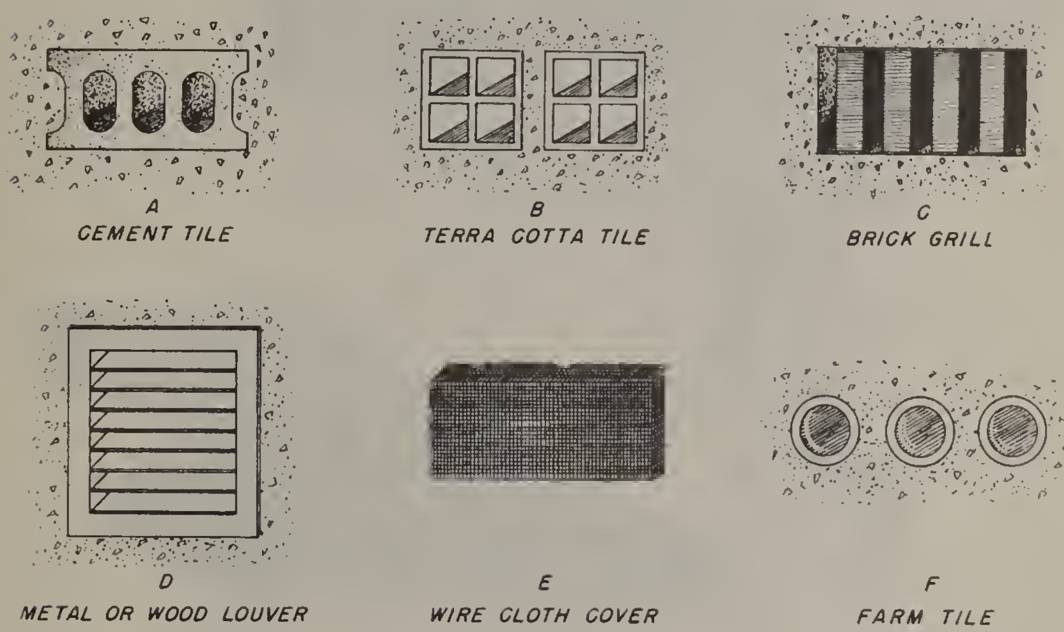

FIGURE 14.—*Representative types of ventilators.* These sketches illustrate simple ventilators that may be used in masonry walls for condensation control in crawl spaces. The actual areas of the openings should conform to the requirements given in the section entitled, "Good practice recommendations." The wire screen shown in E may be set in the concrete so as to cover the openings. The tile shown in sketches A, B, and F do not require special forms. For adequate vermin control, openings in wire cloth should not be larger than one-quarter inch. They are considered necessary over all types of ventilators.

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BASEMENTLESS HOUSE, CRAWL SPACE WITH SOIL COVER

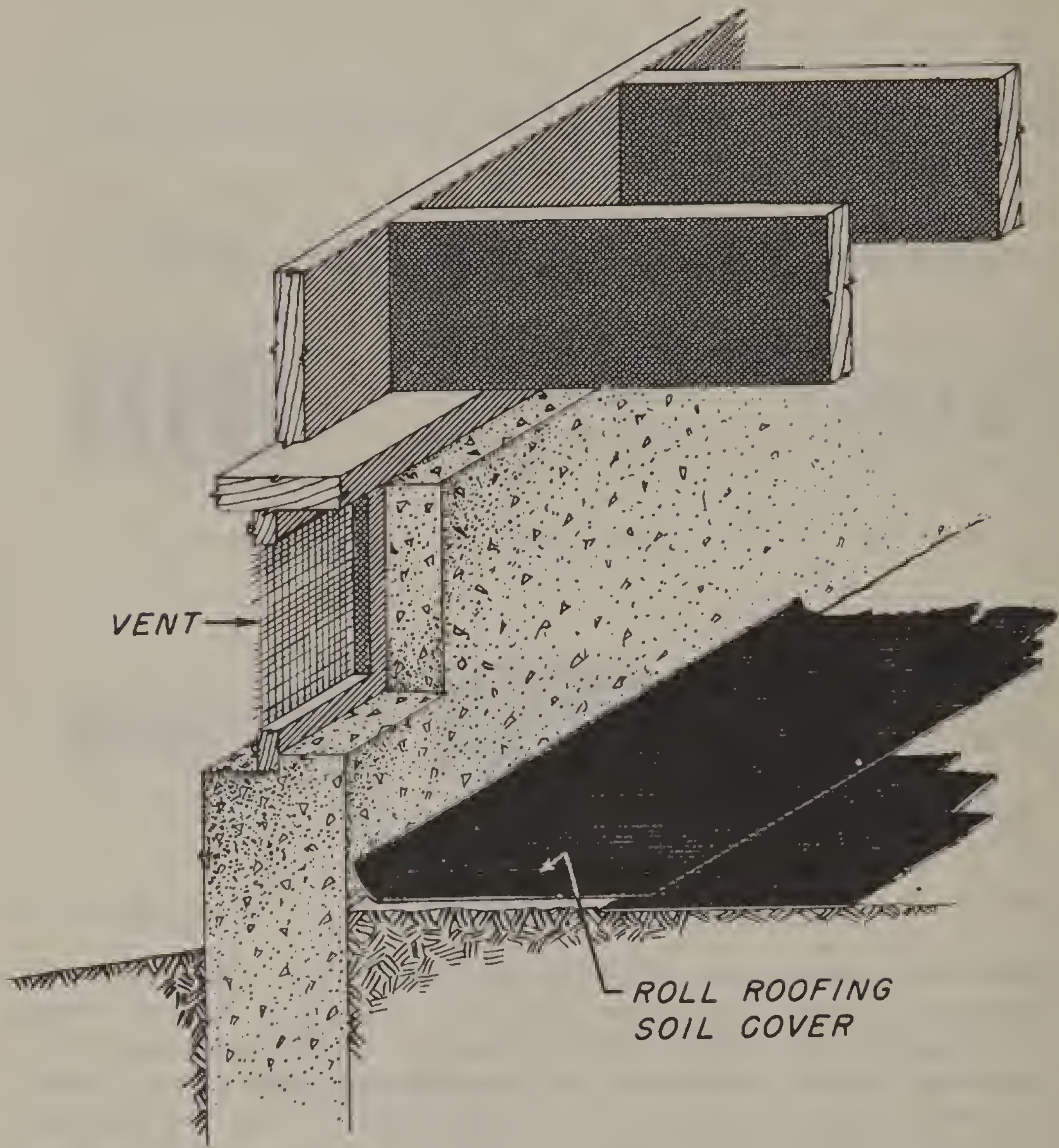

FIGURE 15.—*Basementless house, crawl space with soil cover.* Condensation control is obtained by means of roll roofing weighing at least 55 pounds per 108 square feet laid over the surface of the soil with edges lapping at least 2 inches and supplemented by ventilation. The soil need not be perfectly smooth for the roofing material will become soft and will conform to the contour of the soil within a short time. Covers of this kind greatly restrict the evaporation of water and somewhat less ventilation is needed than when no covers are used. The soil surface below the building should be above the outside grade if there is a chance that water might get inside the foundation wall. The soil cover is especially valuable where the water table is continually near the surface, or the soil has high capillarity.

BASEMENTLESS HOUSE, CRAWL SPACE WITH GRAVEL FILL

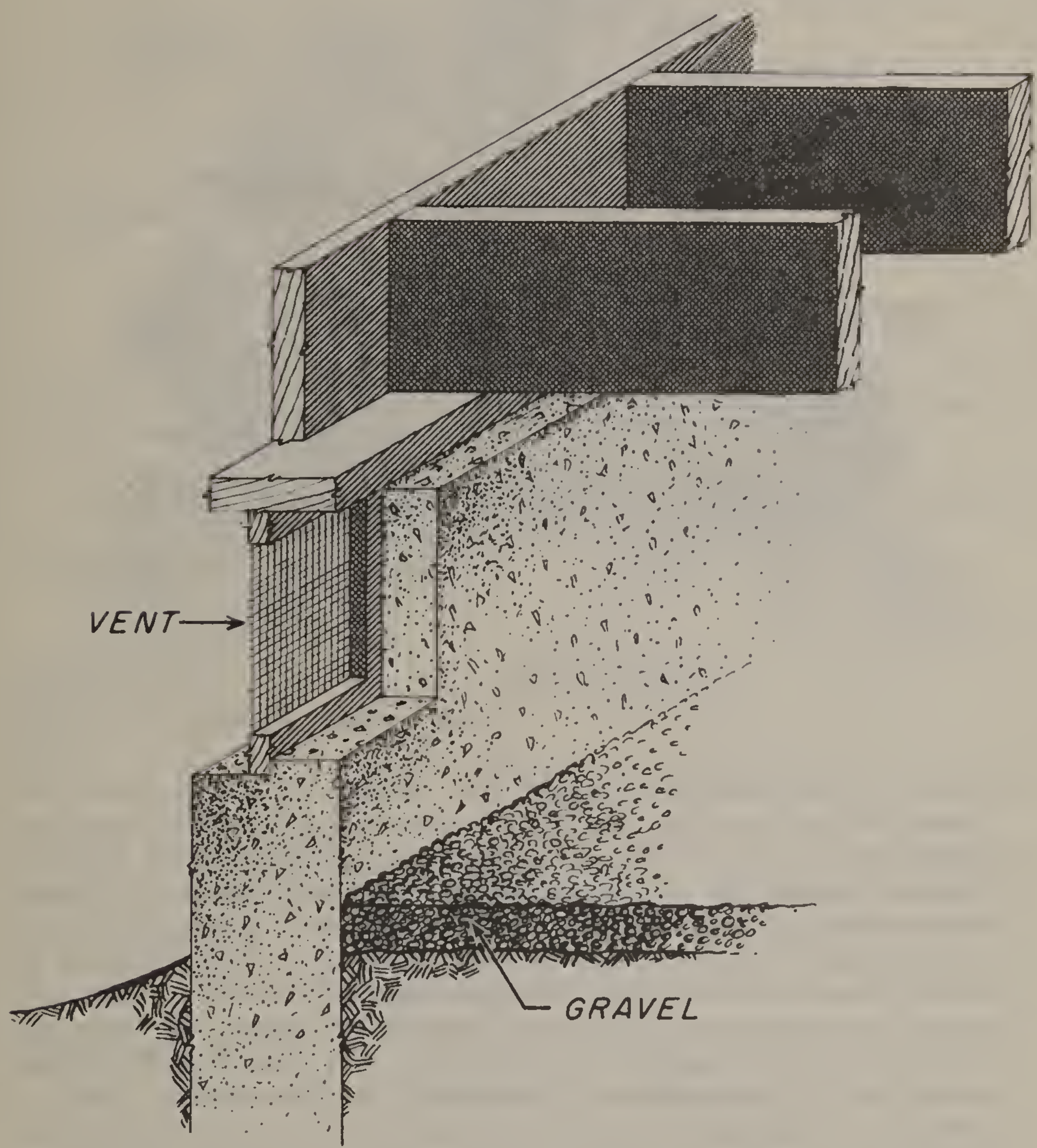

FIGURE 16.—*Basementless house, crawl space with gravel fill.* Condensation control is obtained by about 4 inches gravel, the smallest granules being not less than one-eighth inch in diameter. Smaller granules would induce water migration by capillarity and are therefore undesirable. This gravel cover is not so effective as roll roofing shown in figure 15 so that more dependence on ventilation is needed.

BASEMENTLESS HOUSE, FLOOR DETAIL NO. 1

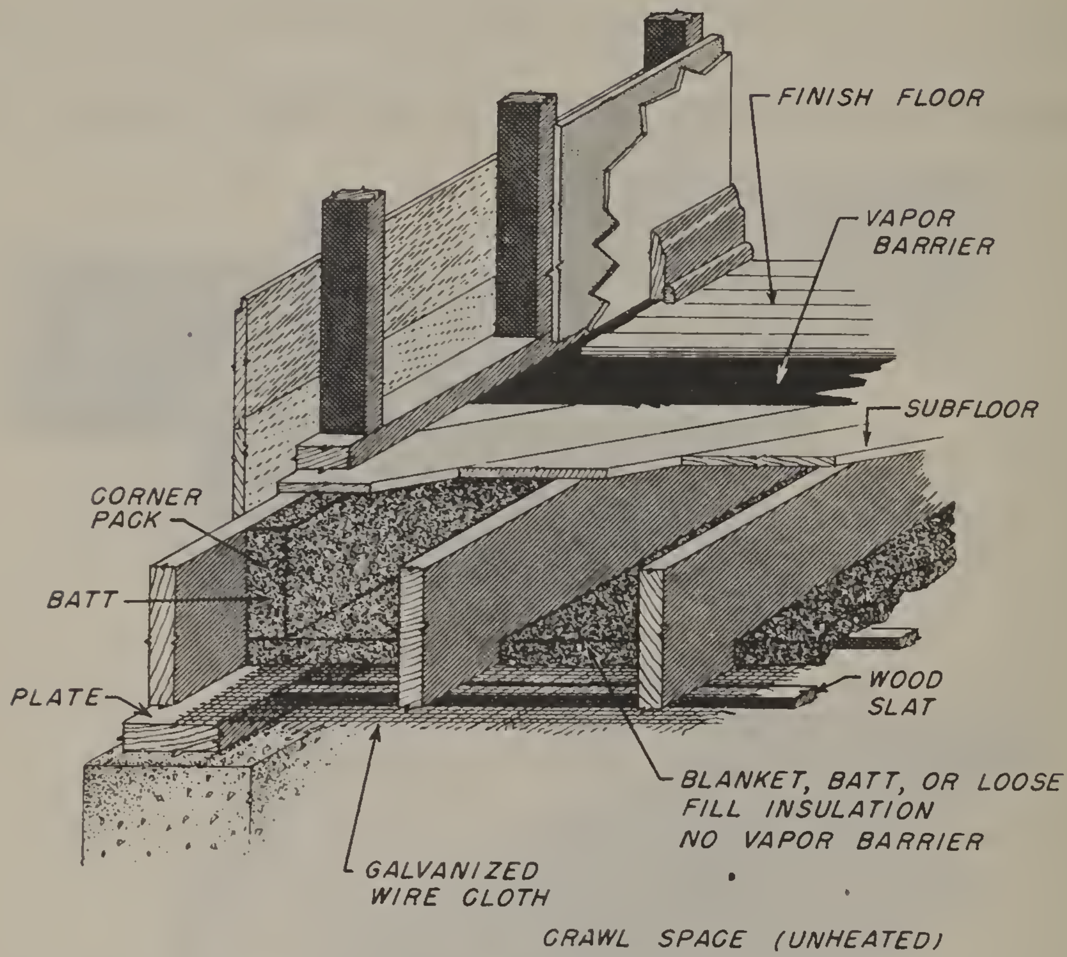

FIGURE 17.—*Basementless house, floor detail No. 1.* Because the lower or cold side of the floor construction in this detail is permeable, a vapor barrier is not required for condensation control. However, since the crawl space may in some instances become damp it would be possible for the finish floor to absorb too much moisture and cause buckling or other damage. A vapor barrier is therefore indicated between the finish floor and subfloor. Blanket, batt, or loose-fill type thermal insulation without a moisture barrier is shown supported on galvanized wire cloth and wood slats nailed to the lower edge of the joists. Batts enclosed in paper should be supported on wood slats since the use of stapled, paper flanges are unreliable where damp conditions may exist continuously or even occasionally. Galvanized wire mesh is recommended where lightweight batt, blanket insulation, or fill insulation is used. The wire mesh should be small enough to retain fill material or a kraft or other paper (not shown) can be laid over larger mesh wire cloth. Note the special corner pack along the outside wall which should be thick enough to support itself permanently. If loose fill is used the corner pack should be supported on the plate. Where corner packs are used it is especially important that the crawl space be well vented and that soil covers (fig. 15) be used in wet locations to prevent condensation on the sill behind the insulation. Condensation in such a situation would not be removed rapidly and would tend to cause a decay hazard.

BASEMENTLESS HOUSE, FLOOR DETAIL NO. 2

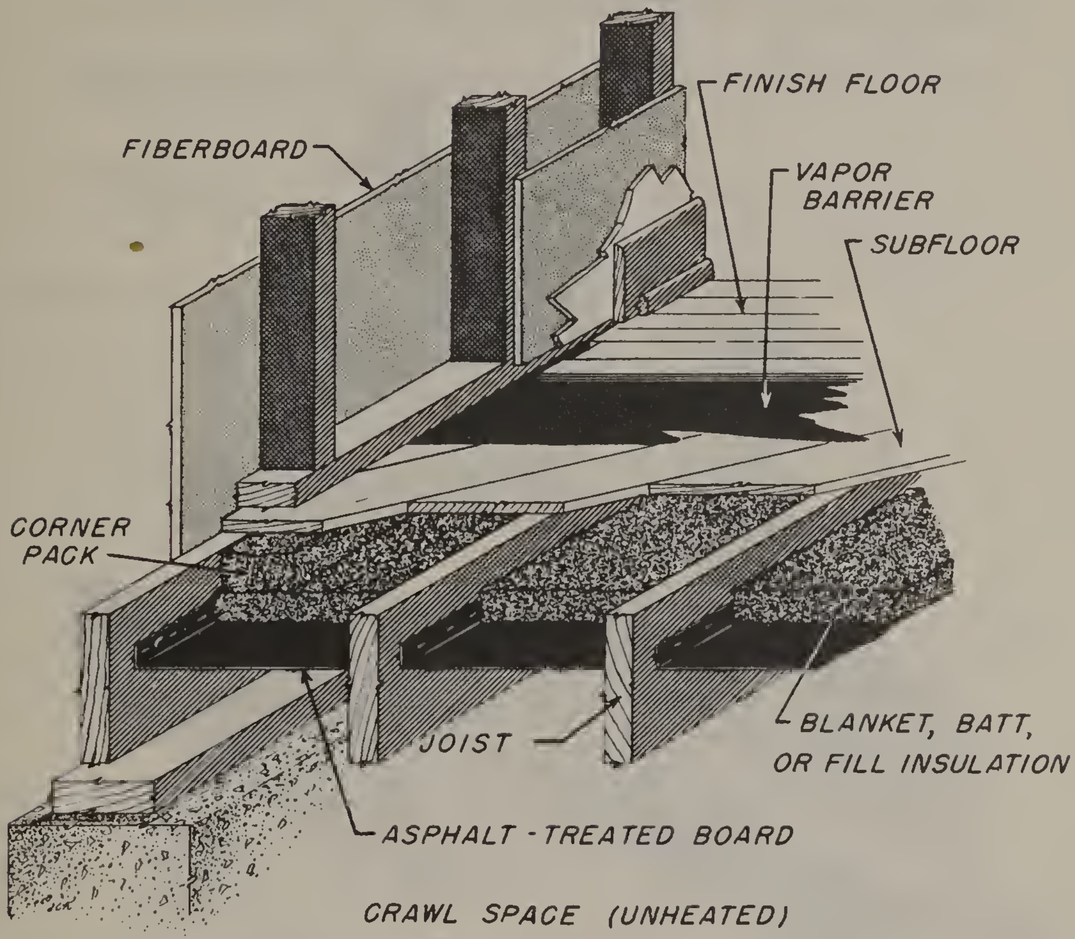

FIGURE 18.—*Basementless house, floor detail No. 2.* Condensation control is not an important feature of this detail. Although the asphalt-treated board may be a good vapor barrier it is not practical to seal the joints between sections of the boards and consequently, water vapor may escape from the floor section. As in figure 17, a paper of vapor-barrier quality is recommended between the subfloor and the finish floor to prevent the finish floor from absorbing too much water vapor from a damp crawl space below. An alternate method of supporting blanket, batt, or fill-type thermal insulation which in this detail may be of the type not having an effective vapor barrier, is with an asphalt saturated stiff board, folded to form channels and installed from the top side of the floor. The flanges of the channel must be securely stapled or nailed to the sides of the joists with corrosion-resistant nails or staples spaced not more than 6 inches center to center. The board may be fastened to the lower edge of the joists if there is sufficient working space below the floor. Corner packs of insulation to provide warmer floors near the outside of the building should be placed along the outside joists or headers to build the insulation up to the underside of the subfloor. It may be either fill- or batt-type insulation.

BASEMENTLESS HOUSE, FLOOR DETAIL NO. 3

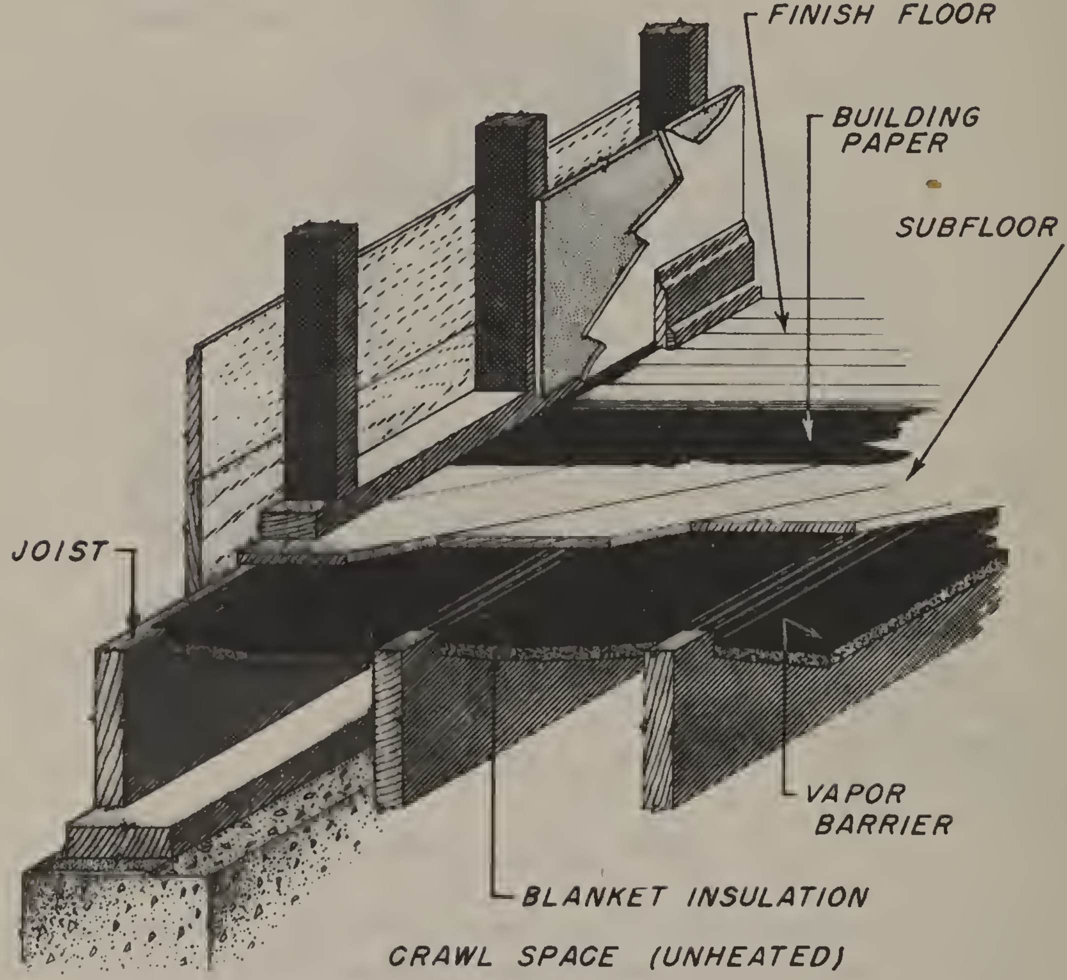

FIGURE 19.—*Basementless house, floor detail No. 3.* Condensation control in this detail requires the blanket insulation to be provided with a vapor barrier of good quality to prevent excessive water vapor in a damp crawl space from reaching the finish floor. It will also prevent water vapor from entering the blanket itself from the warm side. The only condensation problem that might occur in this construction would be in the blanket itself and no serious damage could result to the structure. The paper between the subfloor and finish floor may be a vapor barrier or any building paper of suitable quality. The thermal insulation illustrated is of a blanket type with flanges secured to the top of the joists by staples. The supporting paper is a strong material treated with asphalt capable of supporting the blanket under rather damp conditions and containing a lightweight insulating material. The heavy types of blanket insulation should be supported on good quality cord, wire, or wire mesh.

BASEMENTLESS HOUSE, FLOOR DETAIL NO. 4

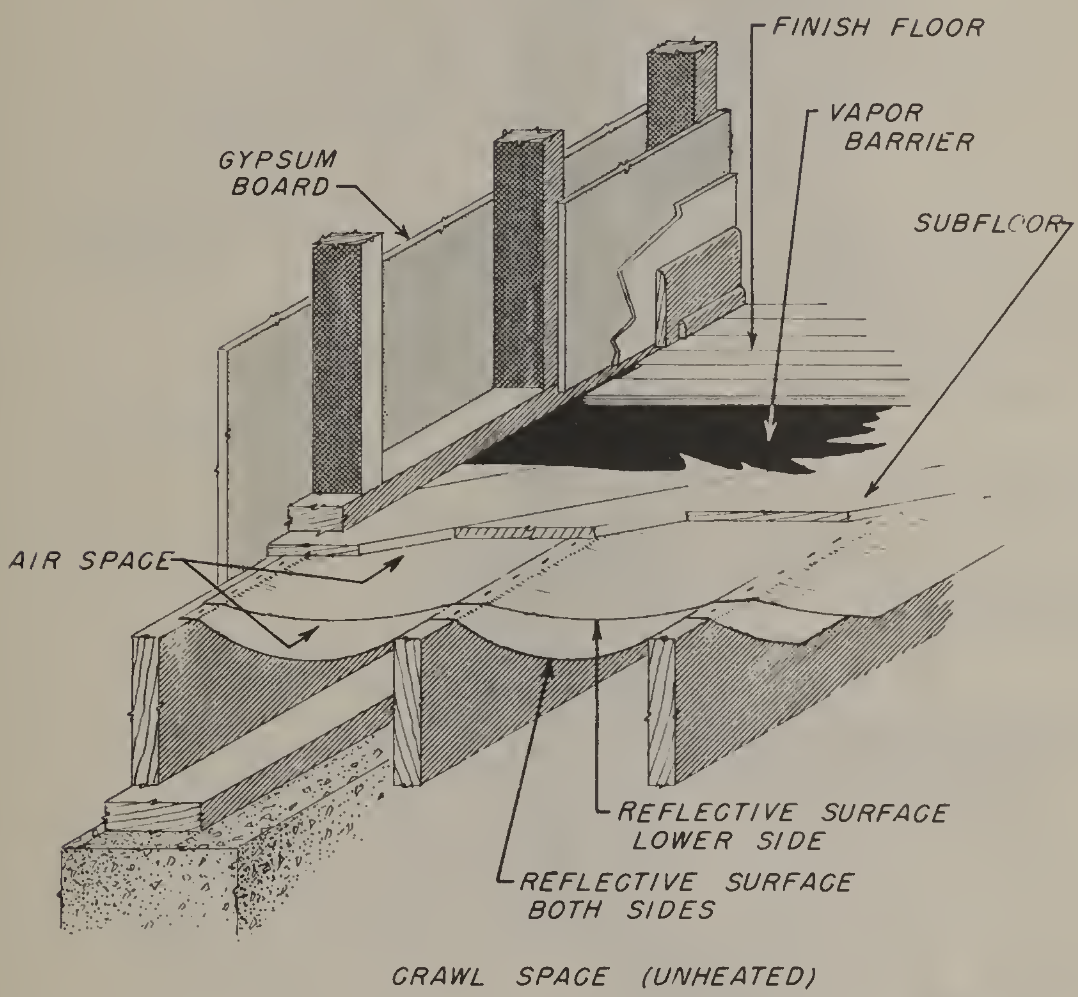

FIGURE 20.—*Basementless house, floor detail No. 4.* Condensation control in this detail depends on a vapor barrier between the finish floor and subfloor. Since the temperature of reflective insulation may be low enough at times to condense water vapor, this arrangement is desirable. Thermal insulation of the reflective type shown in this detail may be applied in single or multiple sheets but it is important that an air space of at least three-fourths of an inch be left between it and adjoining surfaces. Cellular reflective insulation could be used in this detail. A reflective surface on the upper side is not necessary since dirt will readily drop between the boards and destroy the effectiveness of the reflective insulation.

OUTSIDE BASEMENT WALL, DECORATIVE FINISH

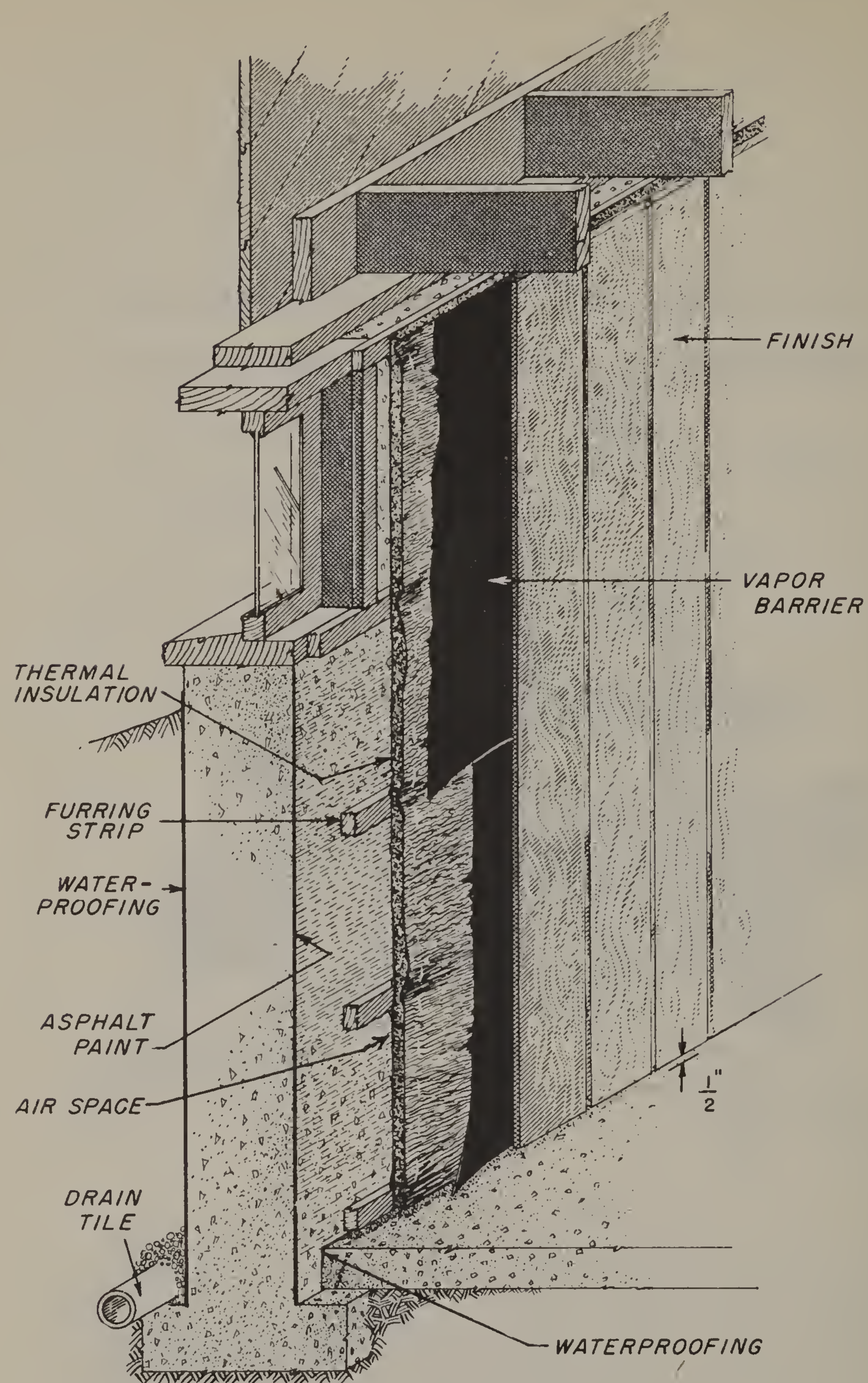

FIGURE 21.—*Outside basement wall, decorative finish.* In some houses it is desired to make use of a room in the basement for recreational purposes and in the northern part of the United States this involves a summer condensation problem. Condensation control is obtained by a vapor barrier placed behind the wood surface, running parallel to the furring strips and lapped only over solid supports. Its purpose is to prevent accumulation of free water behind the ornamental panel. Thermal insulation of the blanket type without a vapor barrier and with an air space between the wall and insulation is shown. The top and bottom furring strips and those around window and other openings should be continuous to form a good seal. The insulation is not highly essential but will keep the finish wood at a higher temperature, a somewhat lower moisture content, and it will also keep the basement warm in the winter. Since soils are generally moist and frequently contain free water, means for keeping the masonry wall as dry as possible are needed. In wet soils a drain tile near the footing and a waterproof coating on the outside of the wall are recommended. A good coat of asphalt paint on the inside of the masonry wall is recommended. The furring strips should be either the heartwood of a durable wood, such as redwood or southern cypress, or be treated with a good wood preservative. The lowest furring strip and ornamental finish should be kept about one-half inch above the concrete floor.

OUTSIDE BASEMENT WALL, PLASTER FINISH, FLOOR TREATMENT

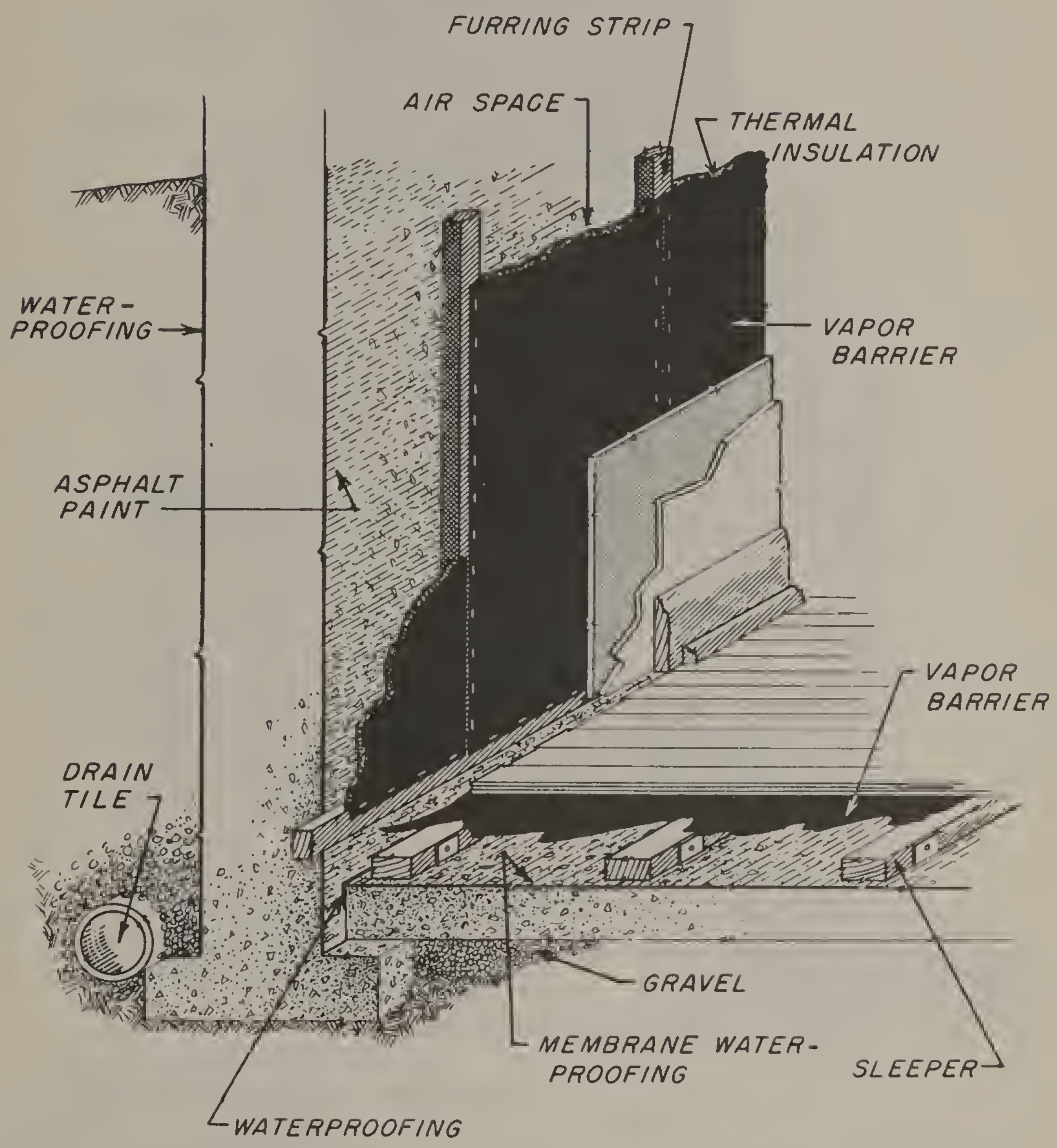

FIGURE 22.—*Outside basement wall, plaster finish, floor treatment.* The notes given for figure 21 apply to the wall section in this detail. Blanket type insulation mentioned in connection with figure 21 is shown in this detail; however, in this case the blanket has a satisfactory vapor barrier. Special attention in this detail is given to the construction of the floor. Condensation control is obtained through the use of a vapor barrier below the finish floor which prevents as far as possible the entry of water vapor into the space between the concrete floor and the finish floor. A membrane waterproofing is recommended over the concrete subfloor. Gravel should be placed below the floor to provide drainage.

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SIDE WALL, FIRST-FLOOR LEVEL

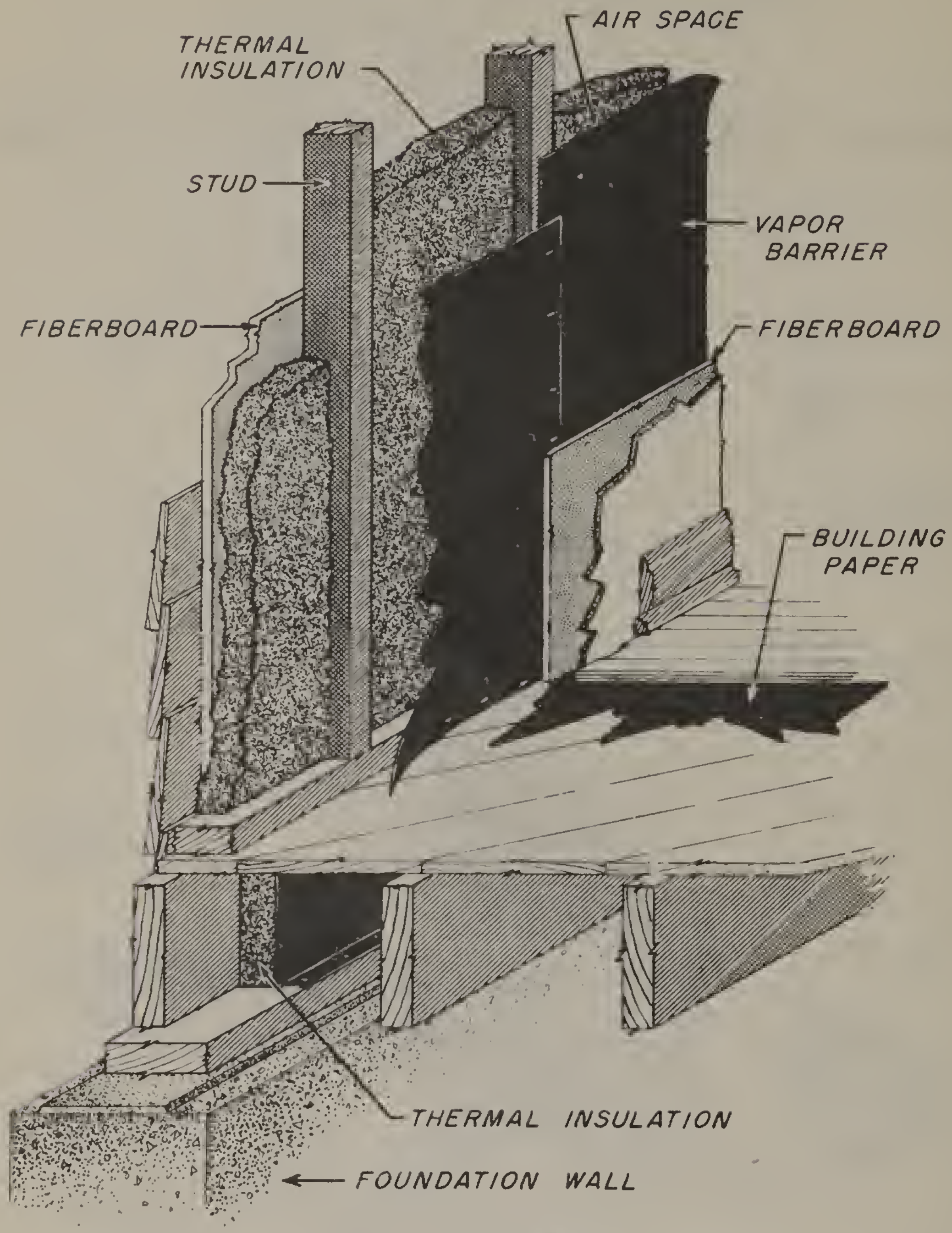

FIGURE 23.—*Side wall, first-floor level* Condensation control in this detail consists of a vapor barrier placed over the inside face of the studs running vertically through the full story height and lapping only over studs. A vapor barrier is also shown in the floor section over the foundation wall. Thermal insulation of the batt type and fiberboard lath and sheathing are shown. The insulation is shown wedged between the studs and against the sheathing as is necessary with some types of insulation. Where the batts are enclosed in paper covers for supporting the insulation, it is sometimes installed on the warm side, leaving an air space next to the sheathing. The thermal insulating value is the same whether the insulation is on the warm or cold side of the wall. The advantage of warm-side installation is that accumulations of water inadvertently entering the wall will be dispersed more readily than if the insulation is against the sheathing boards. Well-installed, high-quality vapor barriers will minimize the possibility of water vapor entering the wall in appreciable quantities. A vapor barrier is considered even more essential when the insulation is against the sheathing.

SIDE WALL, FIRST-FLOOR LEVEL, FIRE STOP

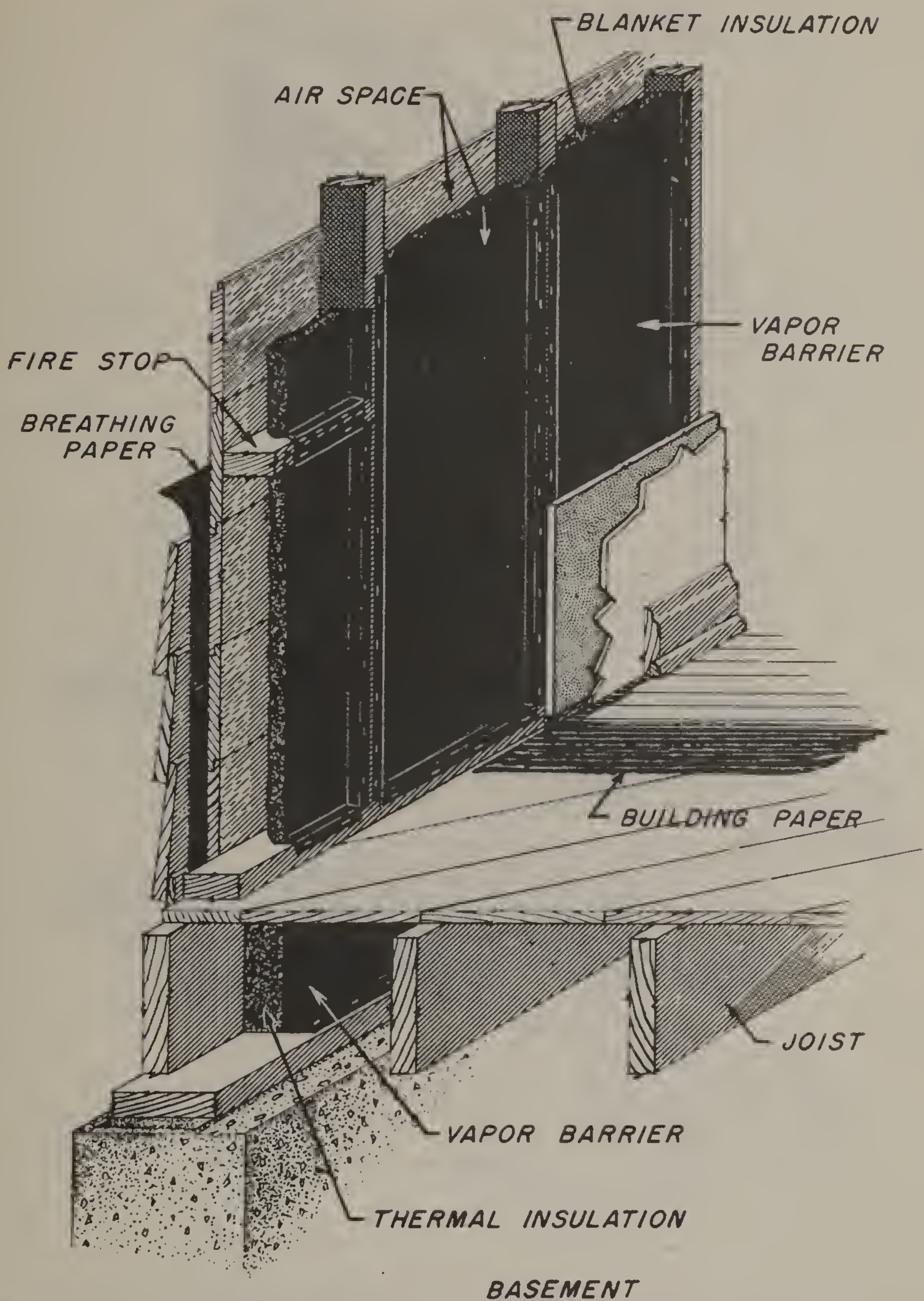

FIGURE 24.—*Side wall, first-floor level, fire stop.* Condensation control is obtained in this detail by the continuous vapor barrier attached to the blanket-type insulation and by thoroughly closing the openings at the top and bottom of the stud spaces or other horizontal obstructions, such as fire stops. The blanket is cut about 3 inches longer than the opening to be covered and some of the insulation is removed and the two covers folded over the edge of the plate or fire stop and stapled securely in place. Thermal insulation is contained within the covers of the blanket, and air spaces on each side are provided. Batt-type insulation is shown above the foundation wall adjacent to the outer joist.

SIDE WALL, FIRST-FLOOR LEVEL

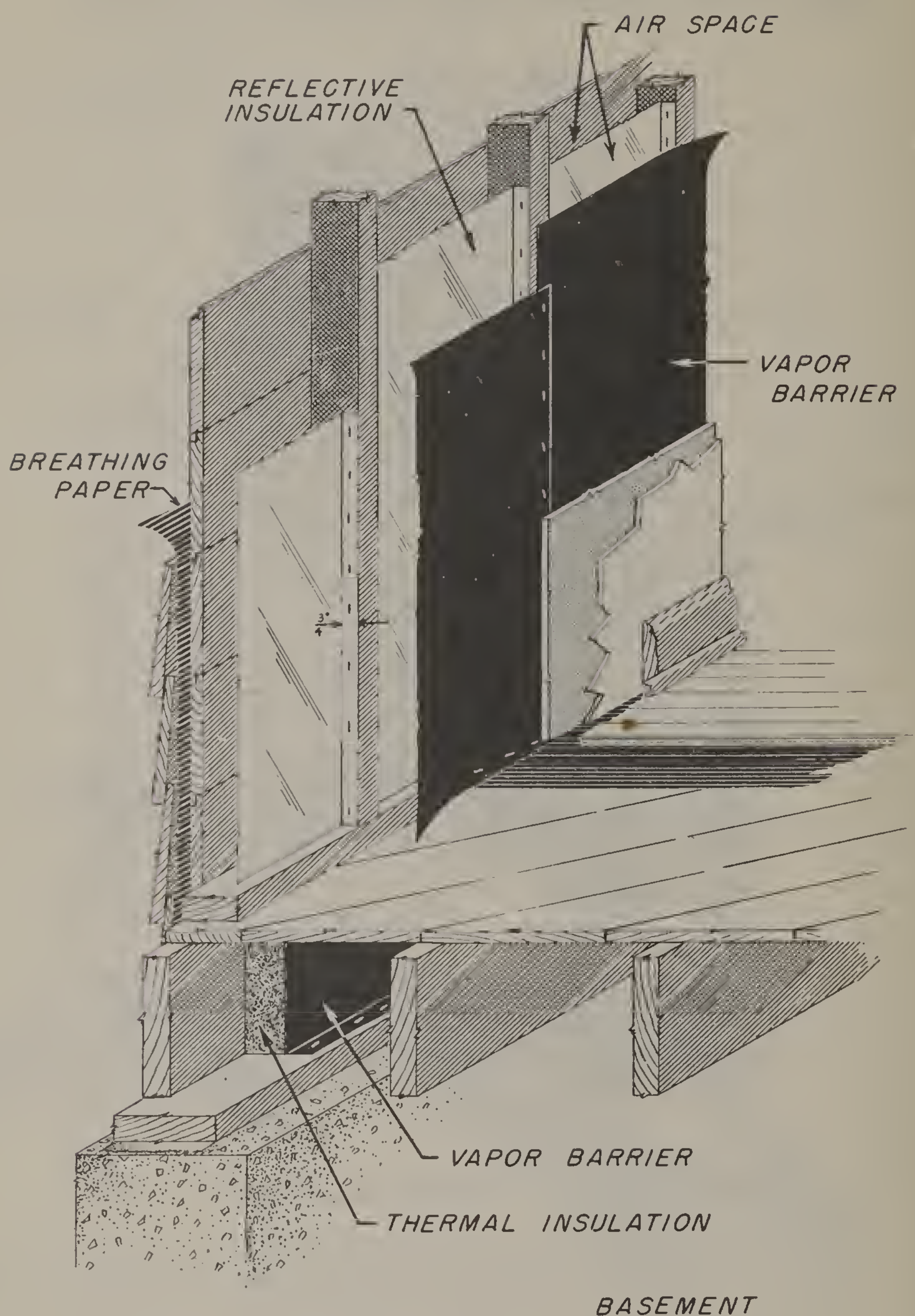

FIGURE 25.—*Side wall, first-floor level.* Condensation control in this detail is obtained by the use of continuous vapor barriers extending full-story height and overlapping the studs. In spite of the fact that since some types of reflective insulation are effective vapor barriers, it is considered necessary to provide a separate barrier since the temperature of the reflective insulation may become low enough to condense water vapor and thereby reduce the effectiveness of the insulation and may eventually cause damage to other building parts. A single sheet of reflective thermal insulation faced on two sides with metallic foil and with two adjacent air spaces provides the greater part of the thermal insulation in this detail. Greater effectiveness can be obtained by the use of additional sheets of reflective insulation to form additional air spaces.

SIDE WALL, FIRST-FLOOR LEVEL

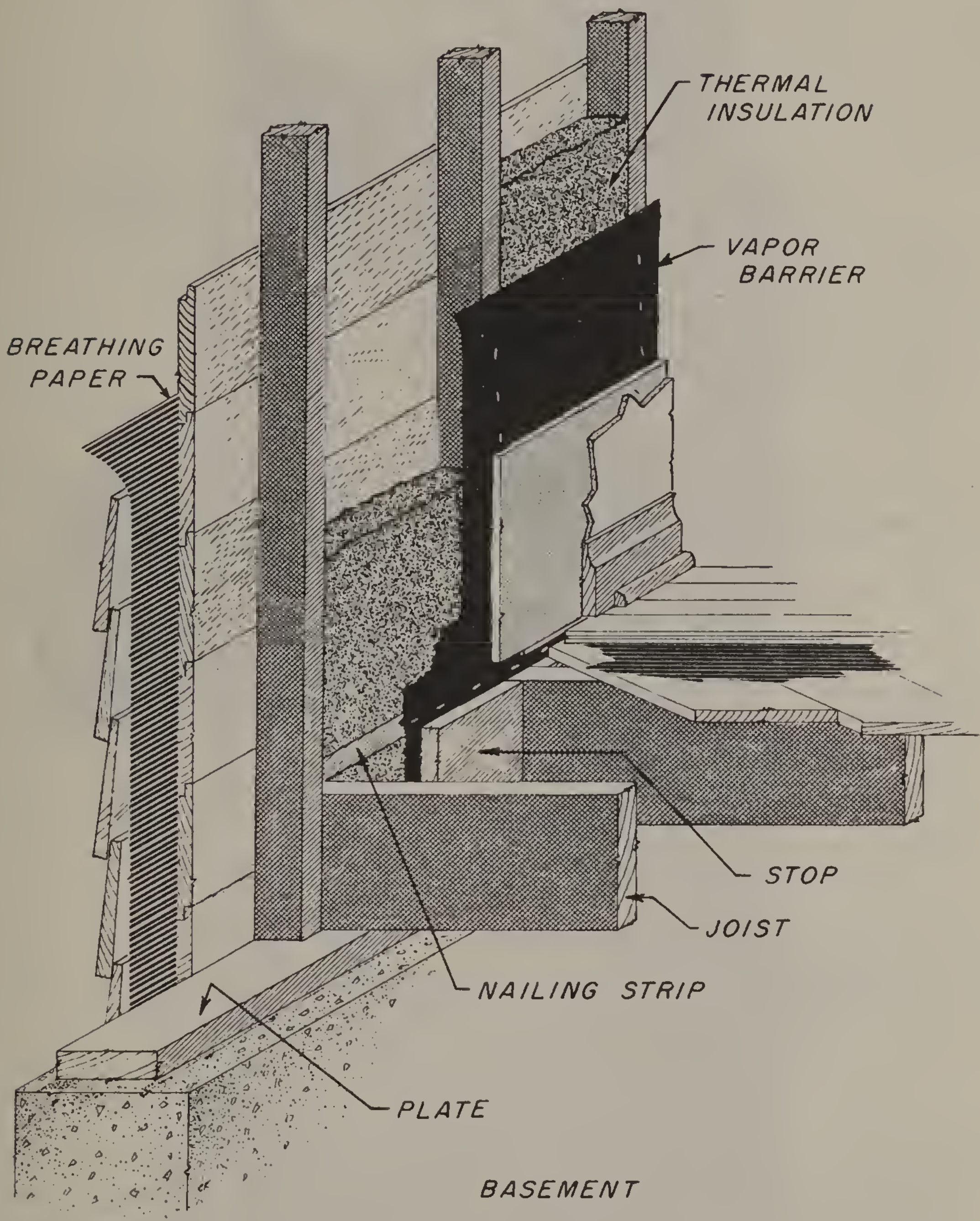

FIGURE 26.—*Side wall, first-floor level.* Condensation control in this detail is obtained by the use of a vapor barrier placed over the studs and extending down between the joists and stapled to a wood strip just at the line of the joist tops. A stop is necessary between the joists to support the insulation and the barrier. Since the paper covers supplied with batts are not long enough to be continuous over the height of the studs, they cannot be considered effective vapor barriers. The thermal insulation shown may be fill- or batt-type material extending below the floor line to the plate.

SIDE WALL, FIRST-FLOOR LEVEL

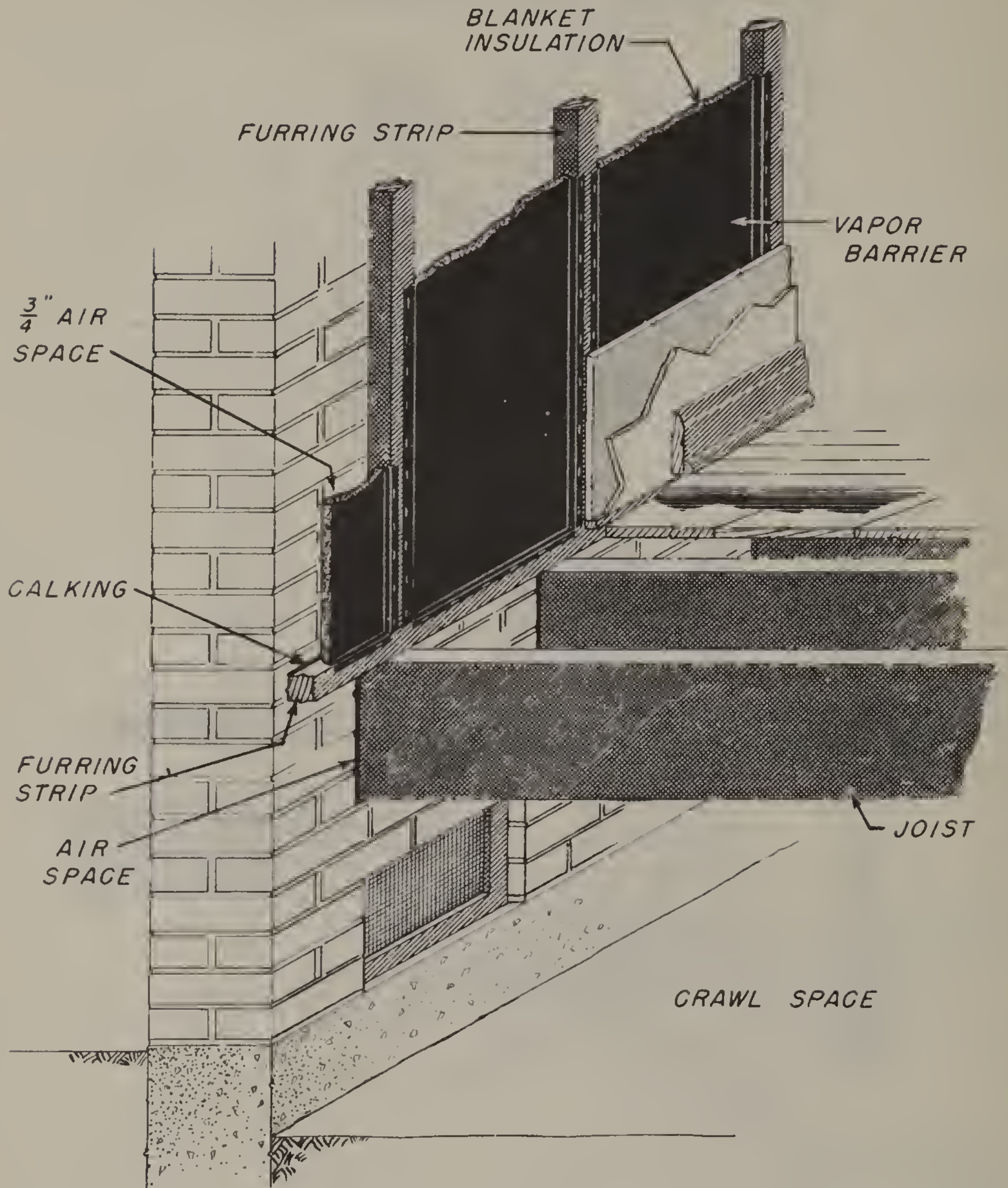

FIGURE 27.—*Side wall, first-floor level.* Condensation control is obtained in this detail by the use of a blanket-type insulating material carrying its own vapor barrier and attached to furring strips running vertically. A special feature of this detail is the horizontal furring strip shown over the top of the joists next to the brick wall; however, it could be laid above the subfloor as well. This strip should be laid tightly against the brick surface and if there are gaps between the brick and the strip they should be filled with caulking compound. The object of this treatment is to prevent the migration of water vapor from the crawl space vertically into the attic where it might become a problem. The thermal insulation consists of a blanket-type insulation with an air space between the blanket and the brickwork. The above covers walls only. See figures 17, 18, 19, and 20 for recommended details of floors over crawl spaces.

VAPOR BARRIER AND THERMAL INSULATION ADJACENT TO A DOUBLE-HUNG WINDOW

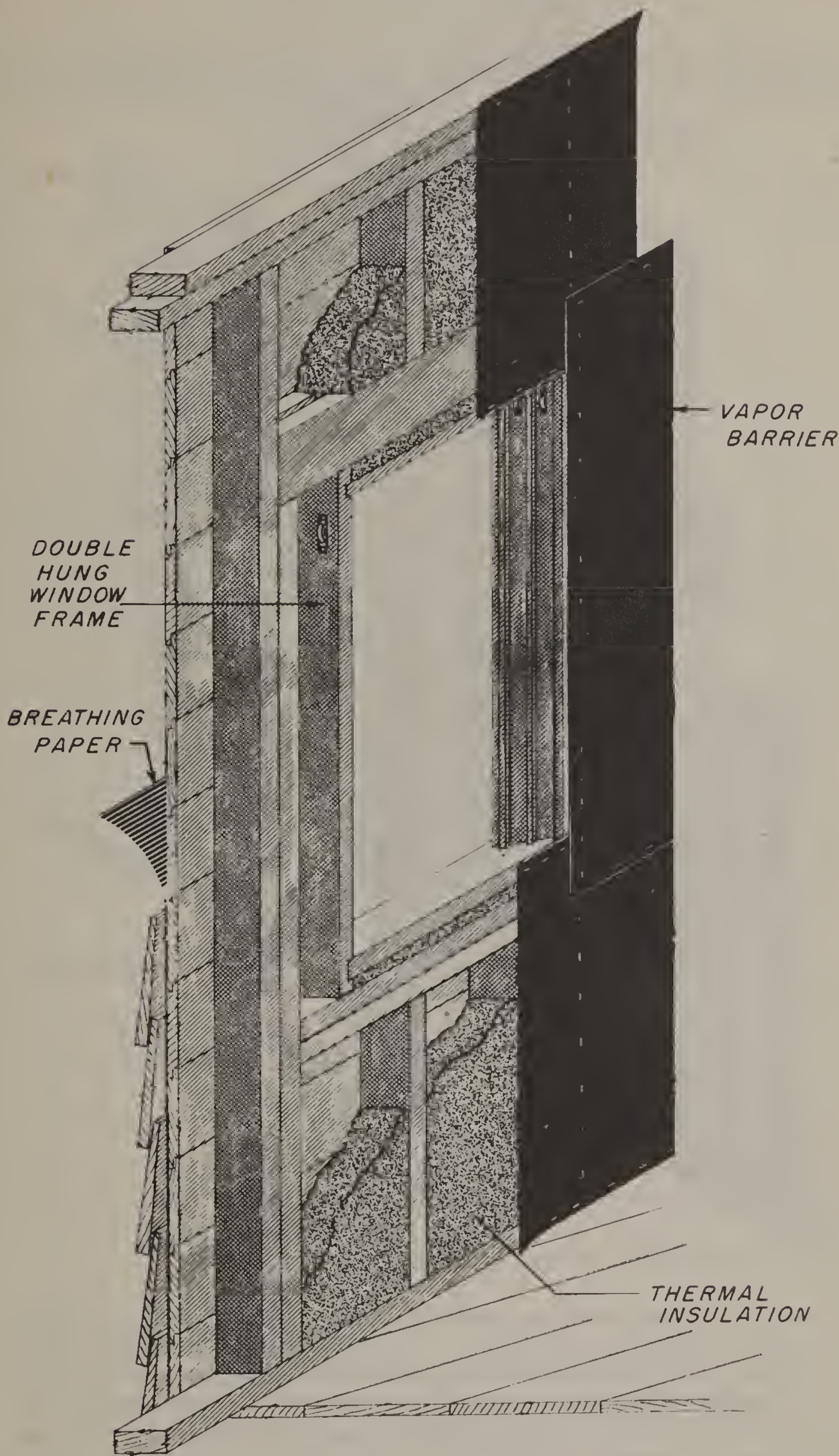

FIGURE 28.—*Vapor barrier and thermal insulation adjacent to a double-hung window.* This drawing indicates the thoroughness that should be used in applying vapor barriers around windows to control condensation. They should effectively cover the frame and the openings at the sides, top, and bottom of the frame. The thermal insulation shown is fill or batt type. All openings except those needed for sash weights should be packed with insulation and covered with vapor barriers as shown.

JUNCTION OF A PARTITION WITH AN OUTSIDE WALL

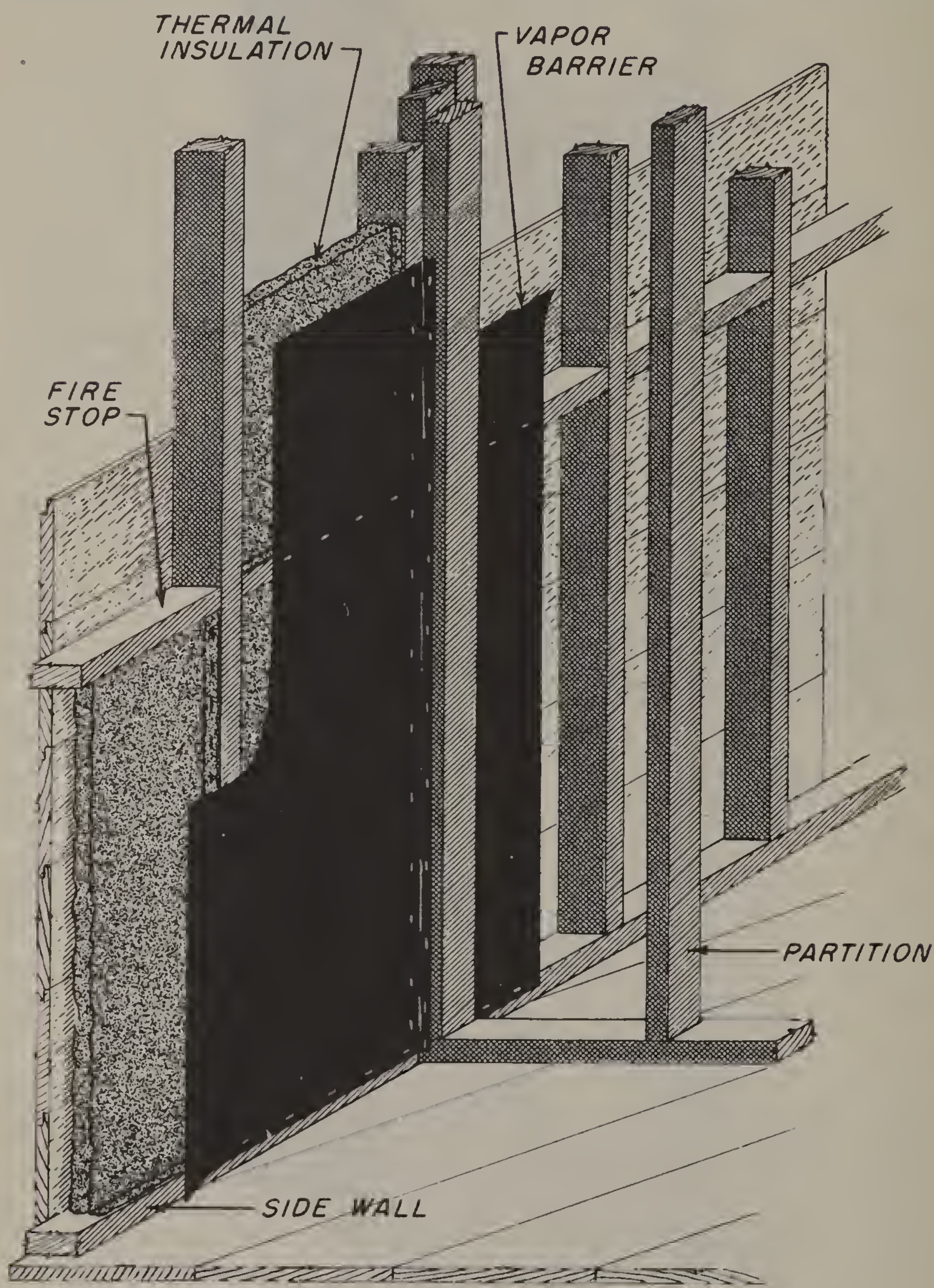

FIGURE 29.—*Junction of a partition with an outside wall.* To provide for condensation control, a vapor barrier is shown fitted and stapled to the partition wall. The thermal insulation shown is a self-supported (stitched) blanket type without a vapor barrier. It is placed in the wall to form two air spaces and is stapled to the studs and plates.

WALL DETAIL, BLANKET INSULATION ATTACHMENT

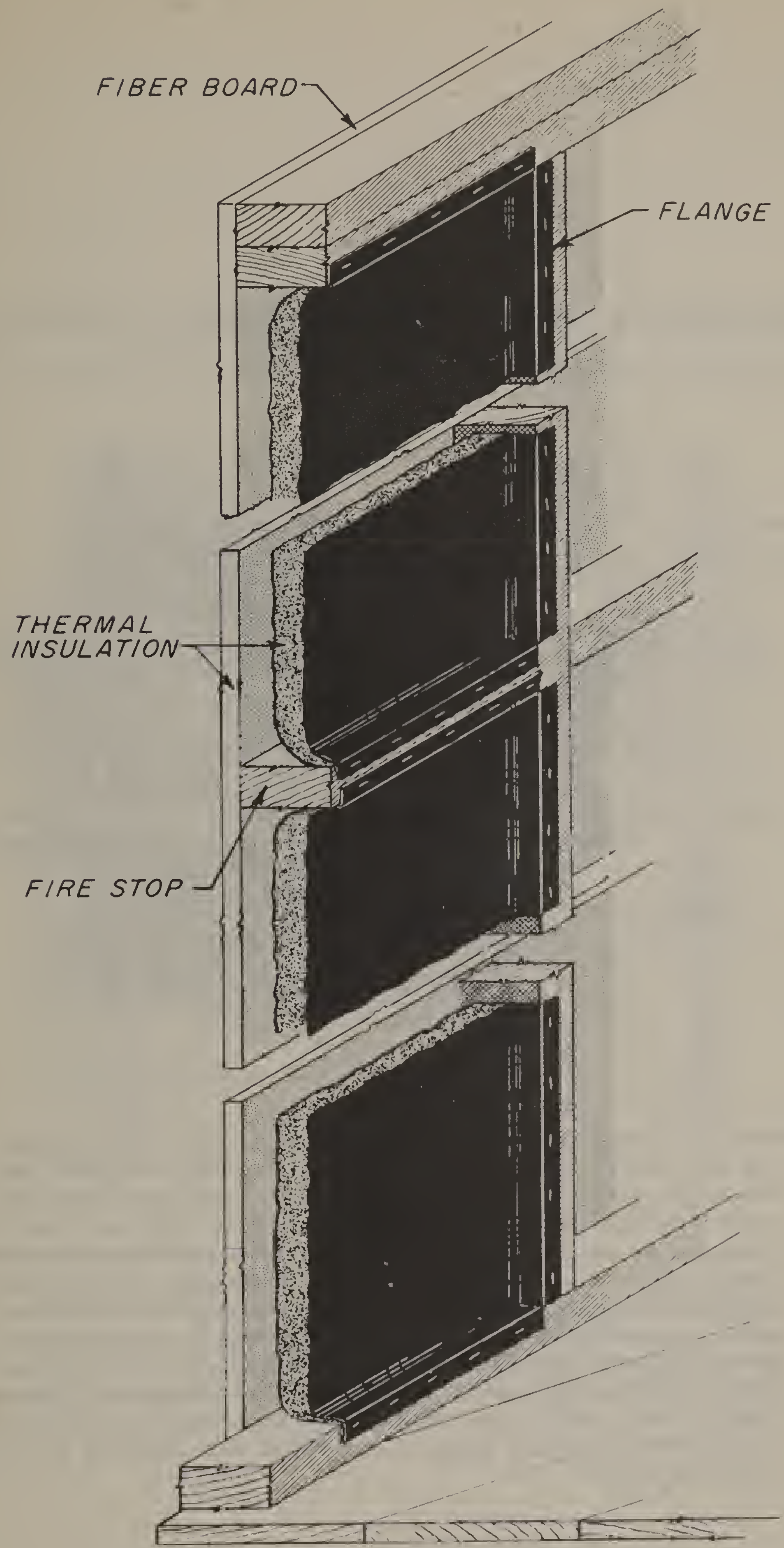

FIGURE 30.—*Wall detail, blanket insulation attachment.* To obtain the most effective use of blanket insulation in condensation control the flanges of the insulation should be stapled to the studs. About 1½ inches of blanket should be allowed at each end for sealing purposes. In order to bring the covers of the blanket together, the fiber along the ends of the blanket should be removed. The thermal insulation indicated consists of low density fiber, two air spaces, and fiberboard sheathing.

JUNCTION OF SECOND FLOOR AND WALL, BALLOON CONSTRUCTION

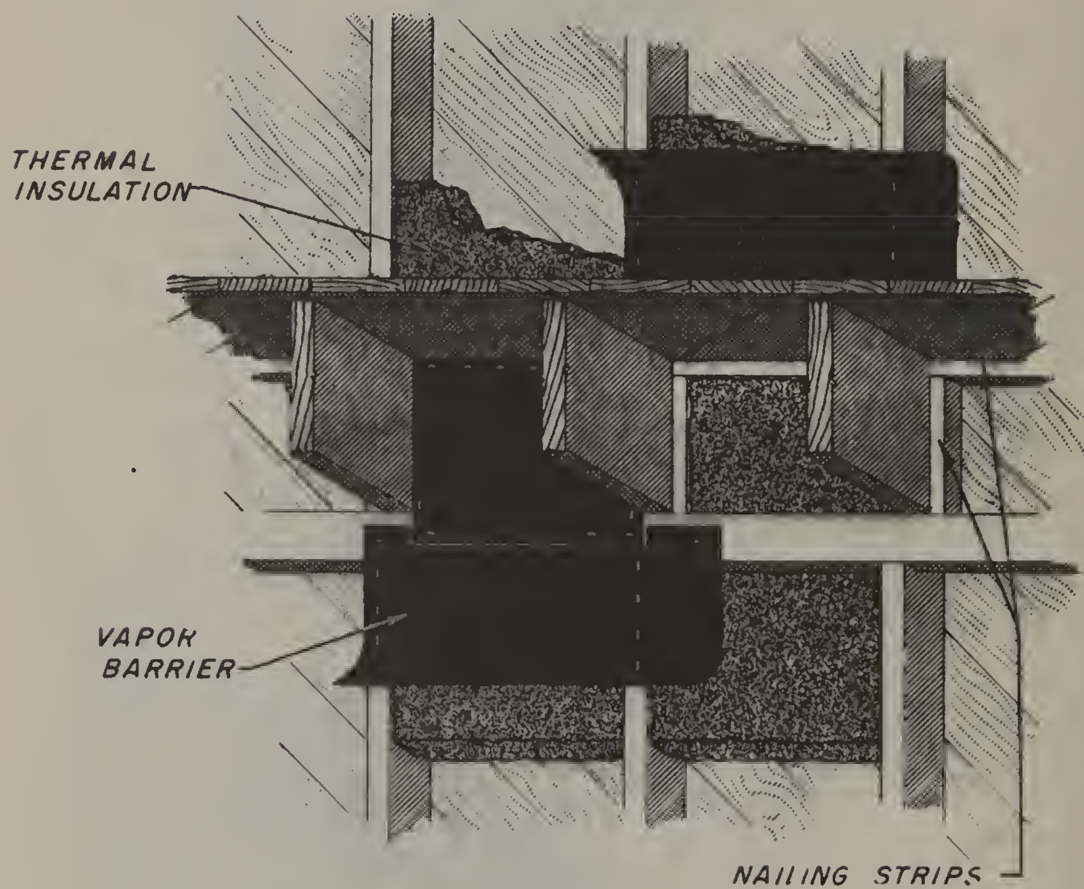

FIGURE 31.—*Junction of second floor and wall, balloon construction.* The floor and ceiling areas enclosing the space between joists provide large surfaces through which water vapor can penetrate. These large surfaces are capable of contributing much more water vapor to the outside wall at the end of the space between the joists than an equal area of outside wall room surfaces. For this reason, well-installed vapor barriers for condensation control are needed to restrict the flow of water vapor into the outside walls. Special attention should be given to the installation of vapor barriers to prevent leakage around them. Heat losses will be as great between joists as in other outside wall areas and wall sections between the floor joists should be as well insulated as the main wall areas.

SIDE WALL, SECOND-FLOOR LEVEL, PLATFORM CONSTRUCTION

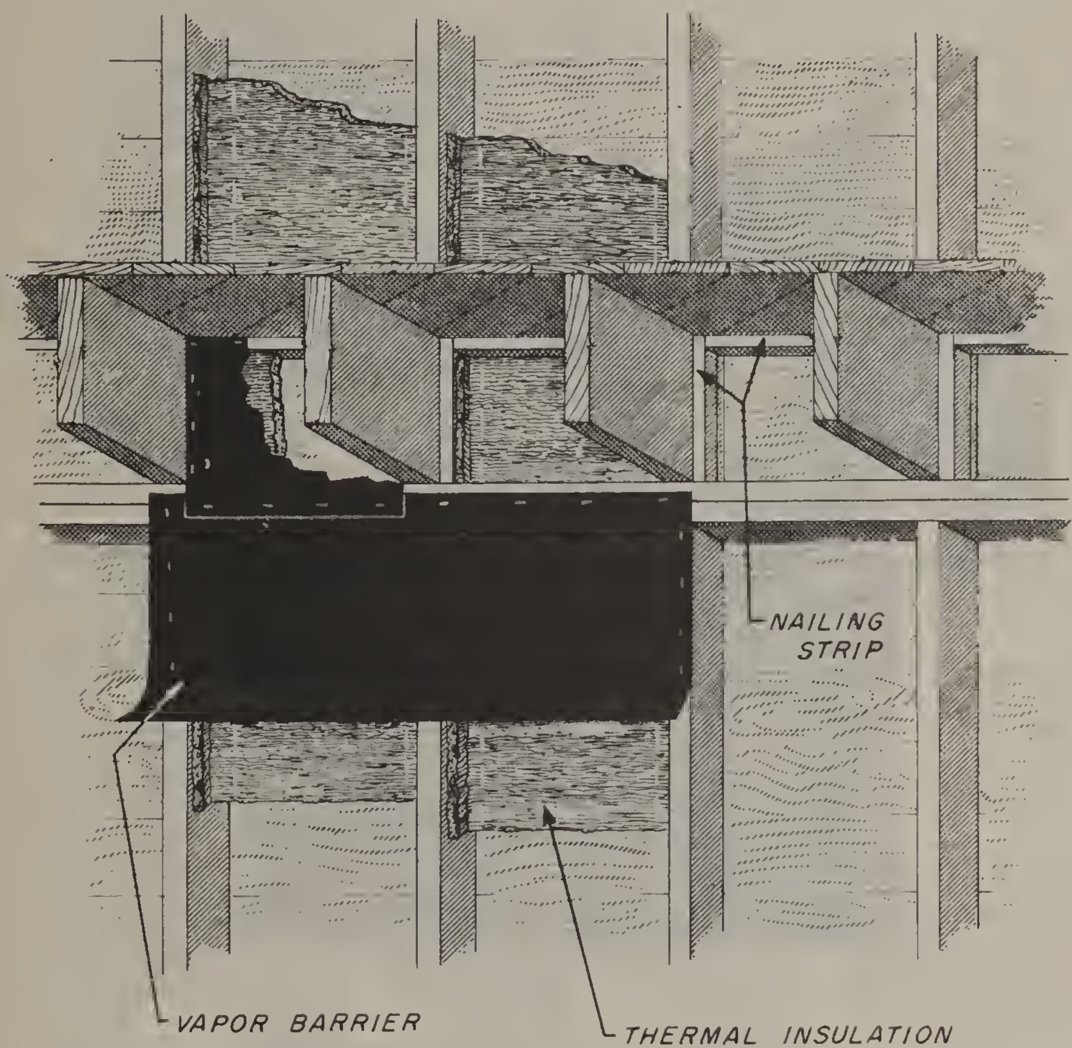

FIGURE 32.—*Side wall, second-floor level, platform construction.* Condensation control is obtained in this detail by the use of a vapor barrier applied over the studs. As in figure 31 the protection of the space between the joists is important because of the large ceiling area feeding vapor to this section of the wall. The thermal insulation consists of a blanket type without a vapor barrier and the two air spaces.

VAPOR BARRIER AND THERMAL INSULATION AT WALL-FLOOR INTERSECTION AT SECOND-FLOOR LEVEL

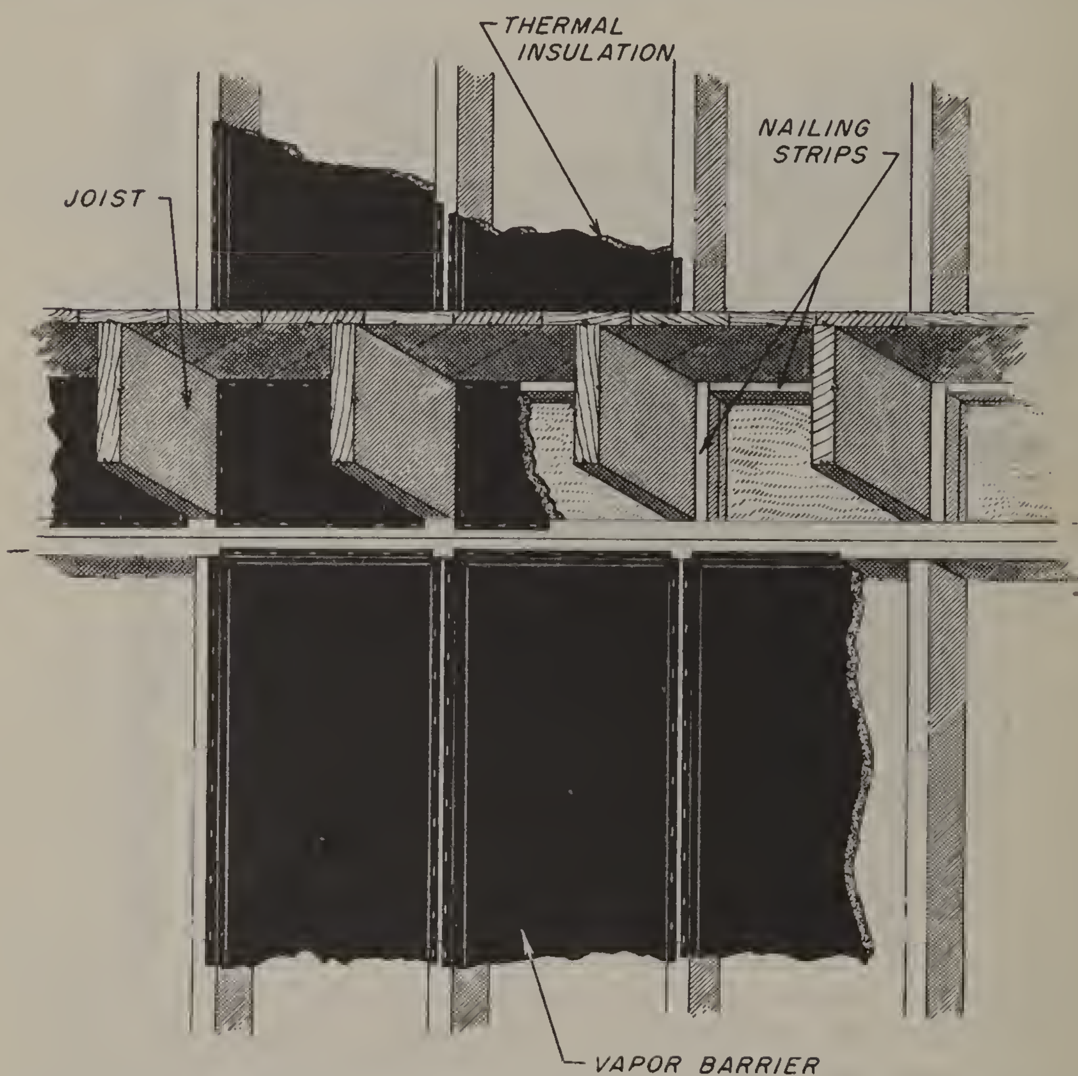

FIGURE 33.—*Vapor barrier and thermal insulation at wall-floor intersection at second-floor level.* This drawing features the installation of vapor barriers for condensation control and thermal insulation of the blanket type faced with a vapor barrier. The detail is similar to that shown in figure 32 except that blanket insulation faced with a vapor barrier is illustrated. Special care should be given to the application of the insulation and vapor barrier between the joists.

SIDE WALL, SECOND-FLOOR LEVEL, JOISTS PARALLEL TO THE SIDE WALL

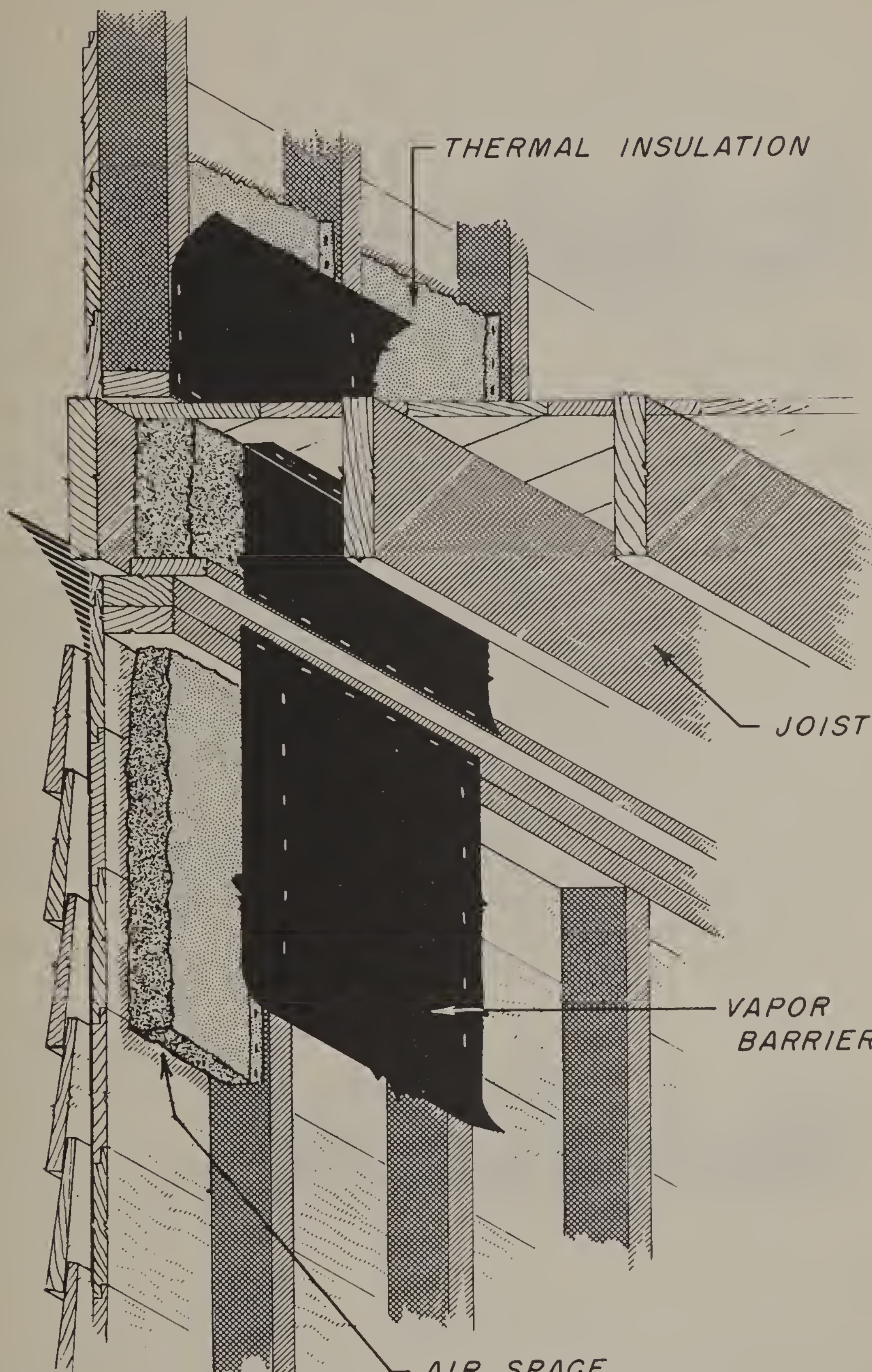

FIGURE 34.—*Side wall, second-floor level, joists parallel to the side wall.* The principles involved in this detail are similar to those of the preceding illustrations 31, 32, and 33. Condensation control is by a vapor barrier applied over the face of the studs and along the wall at the joist level. The thermal insulation is of the batt type without an effective vapor barrier.

CEILING CONSTRUCTION ADJACENT TO AN ATTIC SPACE

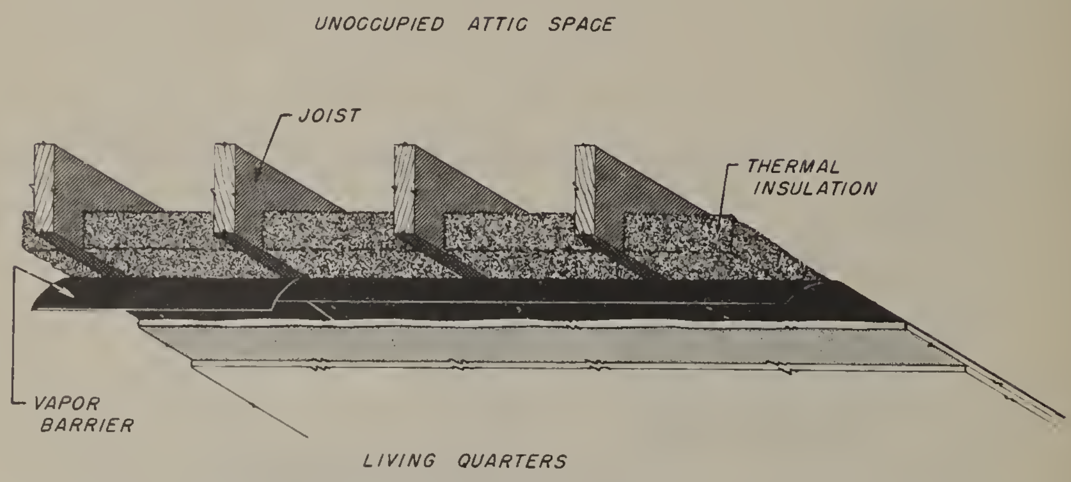

FIGURE 35.—*Ceiling construction adjacent to an attic space.* Condensation control is obtained through the use of a vapor barrier applied below the joists and running parallel to them prior to the attachment of the ceiling. The thermal insulation may be fill or batt type placed after the ceiling finish has been applied.

CEILING CONSTRUCTION ADJACENT TO AN ATTIC SPACE, INSTALLED IN AN EXISTING BUILDING

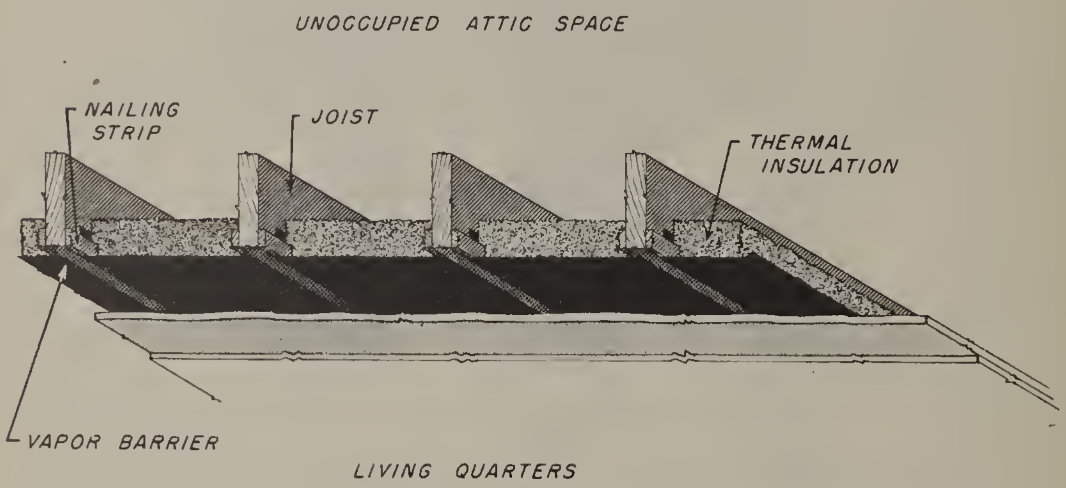

FIGURE 36.—*Ceiling construction adjacent to an attic space, installed in an existing building.* Condensation control is obtained in this detail by a separately applied vapor barrier installed in an existing building and held in place by wood strips laid over the turned-up edges of the barrier. The thermal insulation may be fill or batt type.

JUNCTION OF ATTIC FLOOR, ROOF, AND SIDE WALL

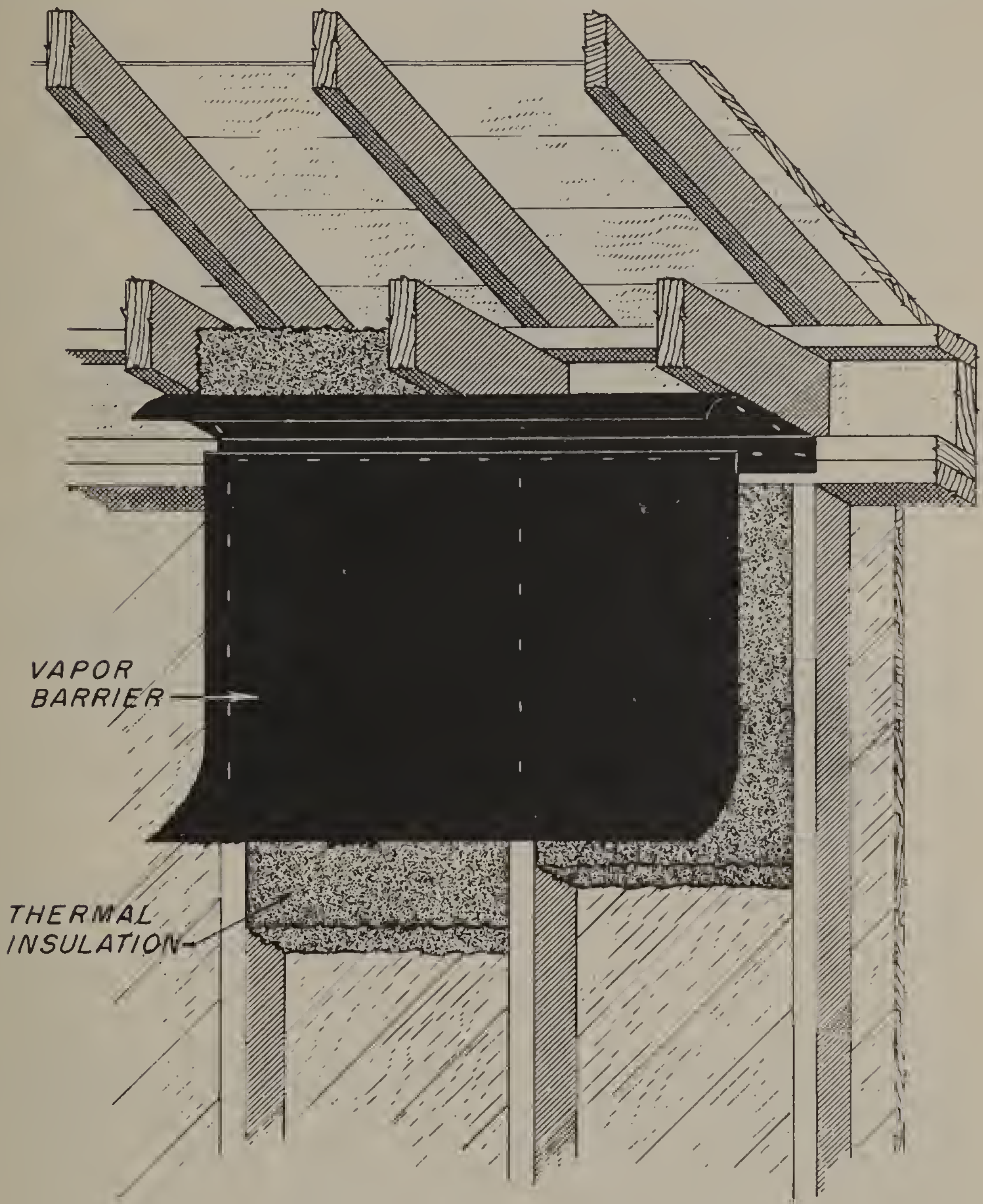

FIGURE 37.—*Junction of attic floor, roof, and side wall.* Condensation control is obtained by the use of a vapor barrier over the face of the studs and lower side of the attic floor joists making a lap on the side wall plate. The thermal insulation is fill- or batt-type material without a vapor barrier.

JUNCTION OF A DWARF WALL WITH THE ATTIC, FLOOR, AND ROOF

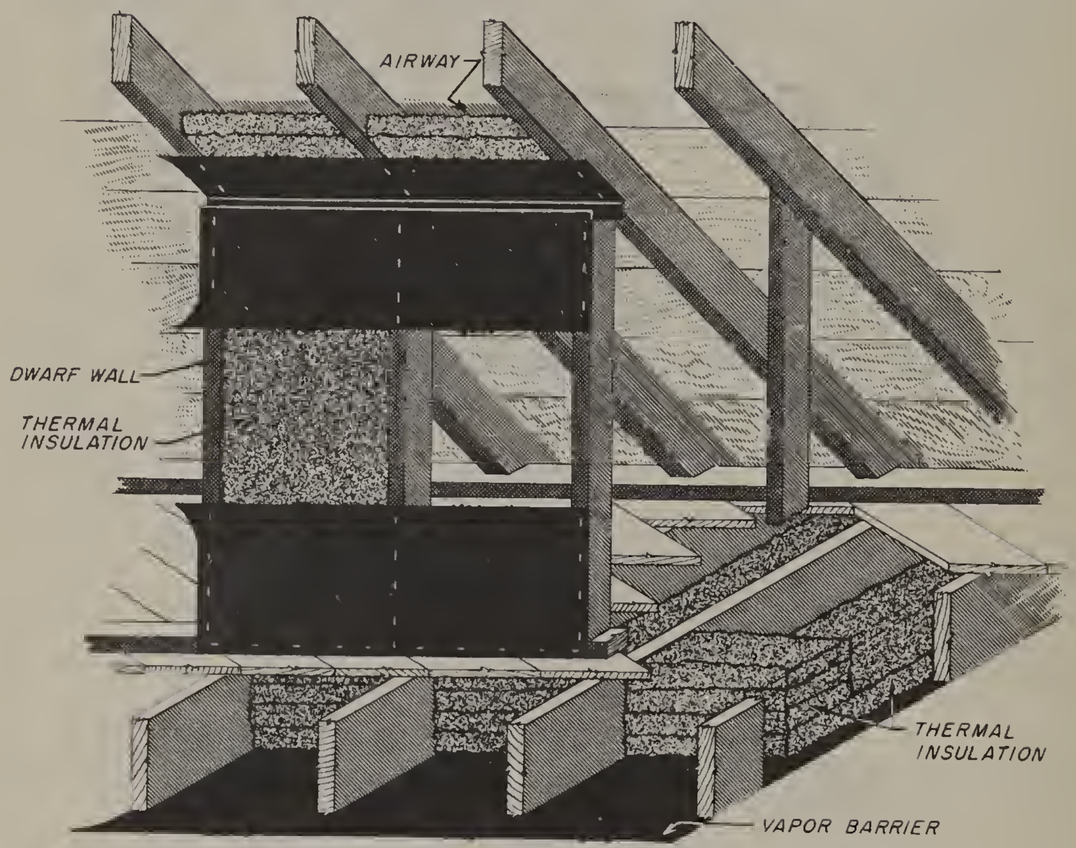

FIGURE 38.—*Junction of a dwarf wall with the attic, floor, and roof.* The vapor barrier on the floor joists provides condensation control in this detail. It covers the entire ceiling; otherwise a barrier should be installed between the joists below the dwarf wall and extending back to the outside wall. It would probably be less expensive and better to cover the entire ceiling with a vapor barrier than to fit barriers between the joists. The vapor barriers are shown lapped where the dwarf wall and roof join. An important point is to provide an airway over the insulation in the sloping portion of the ceiling. Air inlets below the eaves are desirable to provide for circulation of fresh air behind the dwarf wall and up between the rafters above the insulation. The thermal insulation shown is a fill or batt type without vapor barrier.

JUNCTION OF ATTIC FLOOR, SIDE WALL, AND ROOF

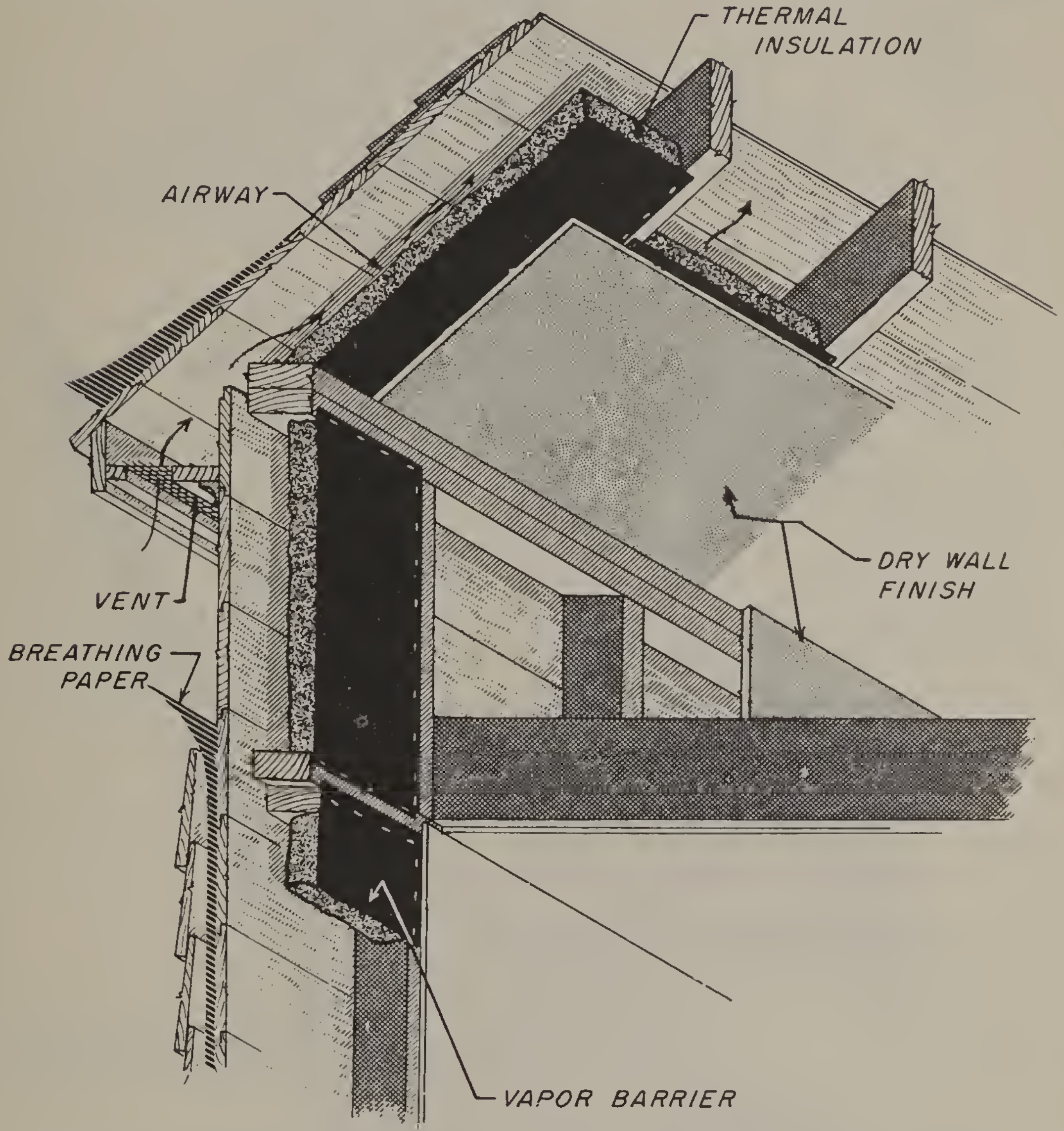

FIGURE 39.—*Junction of attic floor, side wall, and roof.* Blanket-type insulation is shown both in the side wall and between the rafters of the attic roof and should be equipped with a good vapor barrier for condensation control. The thermal insulation applied to the roof is of such a thickness that an airway is provided above the insulation. A ventilator is shown below the eaves to provide for air flow over the insulation and out at roof ventilators overhead. Some form of dry wall finish is suggested along walls and the lower part of the roof to prevent damage to the vapor barrier. See "Good practice recommendations" for sizes of ventilators.

ATTIC AND CRAWL-SPACE VENTILATION, GABLE ROOF

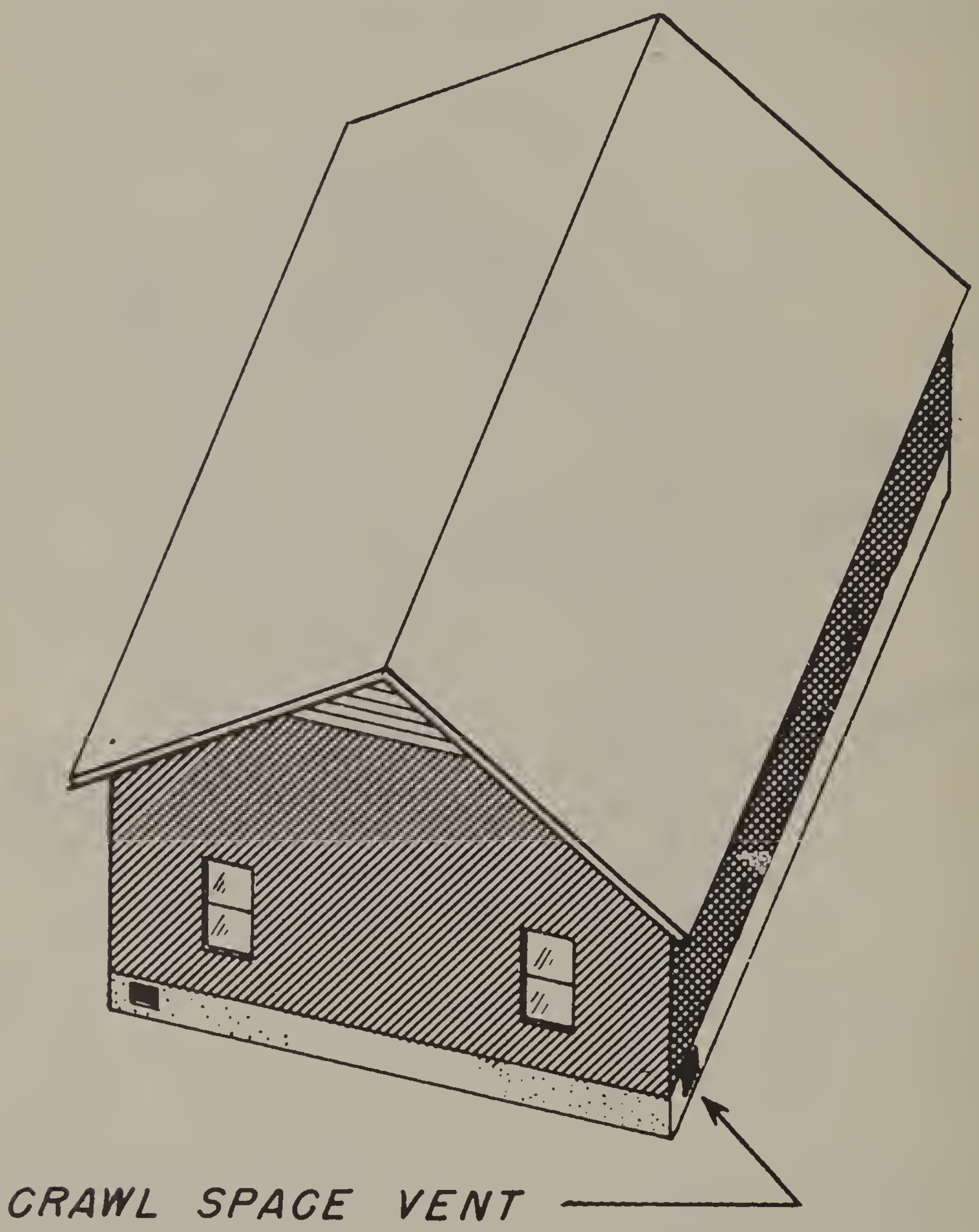

FIGURE 40.—*Attic and crawl-space ventilation, gable roof.* Louvers in the ends of gables, just below the ridge, are an effective means of condensation control in attics. These openings may be supplemented by continuous openings below the eaves, which in conjunction with gable louvers provide air circulation by gravity when air movement produced by wind is lacking. Large vent areas, louvers, and adequate thermal insulation in the ceiling will minimize heat losses in the winter and, in addition, provide cooler living quarters in the summer. For details of attic vents see figure 41 and for sizes see "Good practice recommendations." Vents for the crawl space are shown near the corners of the building near the top of the foundation wall. For details of crawl space vents see figures 12–16 and for sizes see "Good practice recommendations."

LOUVER-TYPE VENTILATOR FOR GABLE OR MODIFIED HIP ROOF

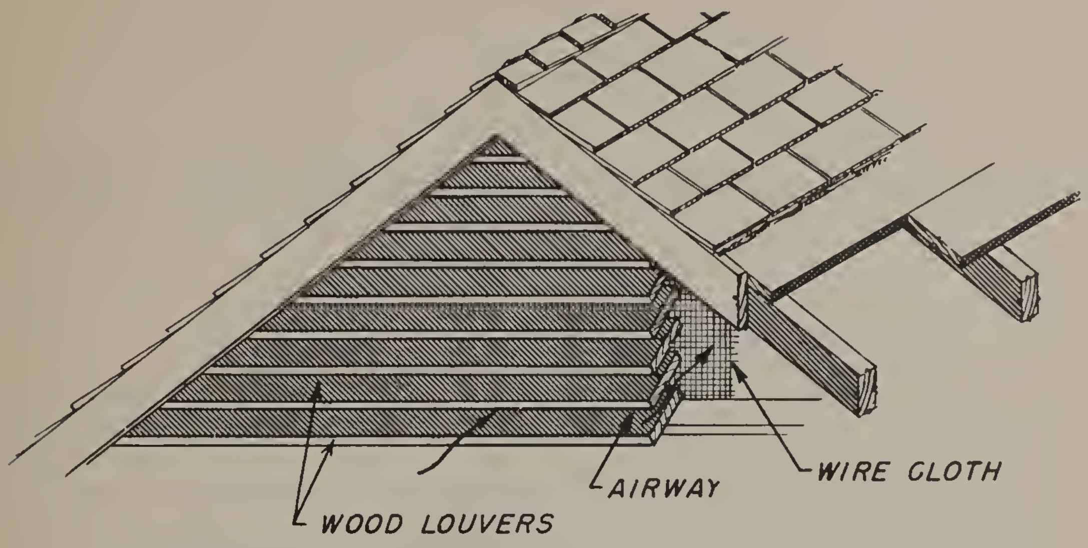

FIGURE 41.—*Louver-type ventilator for gable or modified hip roof.* Ventilation in attic spaces is an effective means of gaining condensation control in attics. Ventilators placed near the apex of the roof are more effective than those placed at lower levels since warm air tends to move upward and out of the building. Wire mesh may be used behind the louver to keep insects out of the building. The mesh size for such construction should be as large as considered practical since fine wire cloth greatly restricts the movement of air and is easily clogged by dust and lint. See "Good practice recommendations" for size recommended.

FLAT ROOF CORNICE

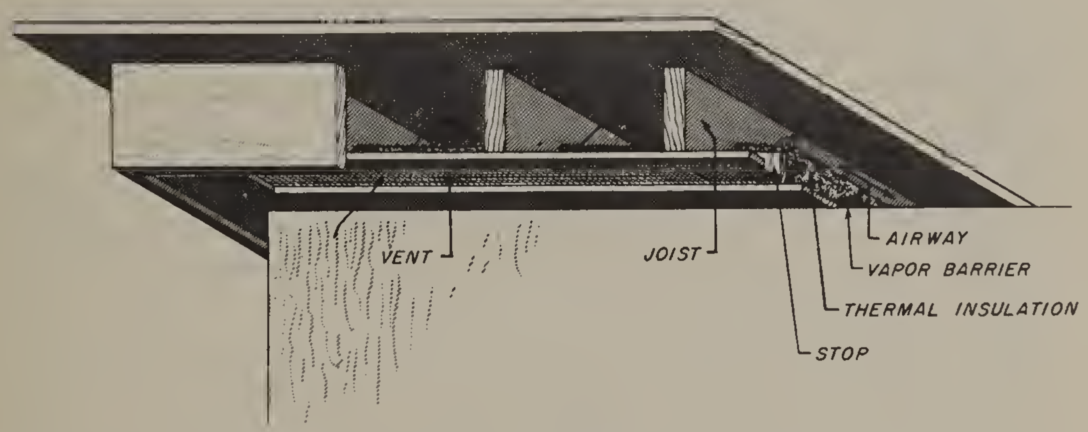

FIGURE 42.—*Flat roof cornice.* Ventilation condensation control in flat roof structures requires careful attention. A vapor barrier should be used on the warm side of the ceiling and vents should be provided below the eave communicating with the space above the thermal insulation between the roof joists. The airways above the insulation should be clear from one side of the building to the other. Vents should be placed as near the outside of the cornice as possible to minimize the amount of snow driven through the ventilators by the wind. See "Good practice recommendations" for vent sizes. The stop shown is recommended where loose fill is used.

VENTILATION OF SPACE BELOW LOW-PITCHED ROOF DECK

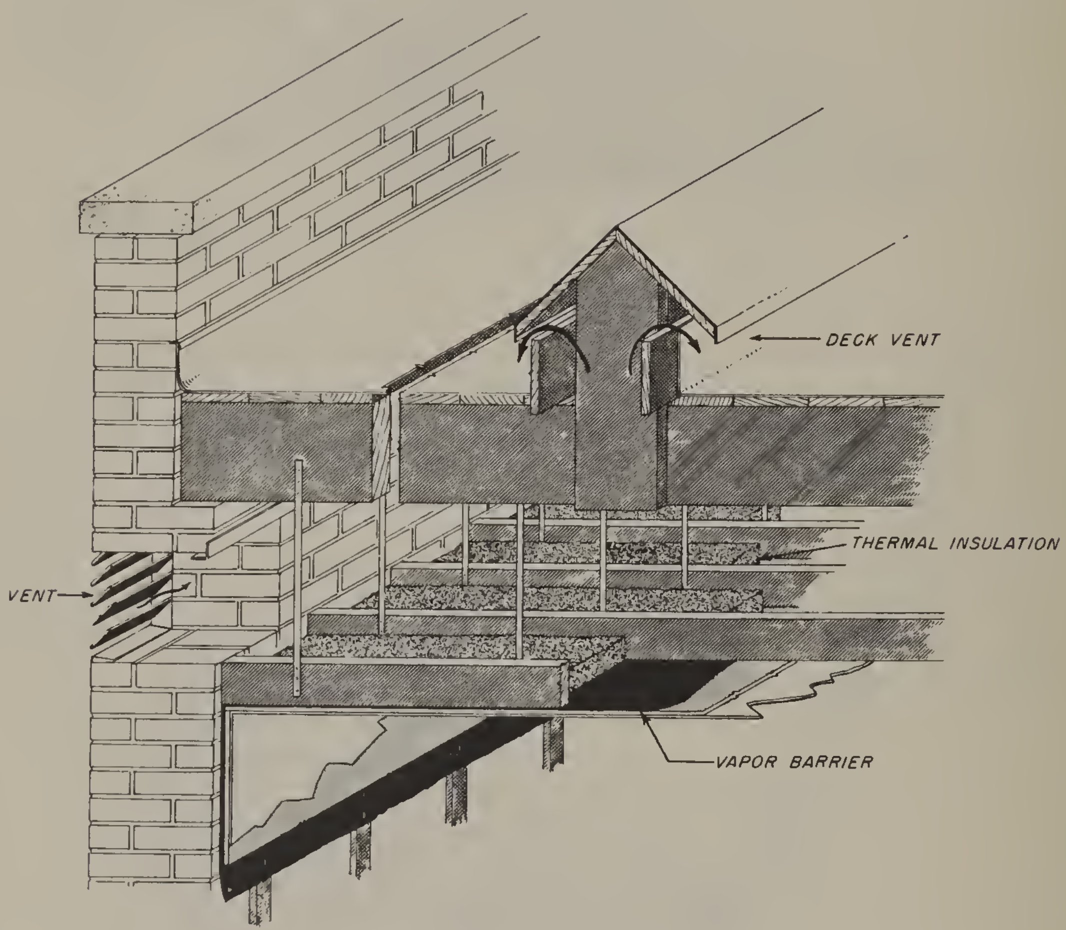

FIGURE 43.—*Ventilation of space below low-pitched roof deck.* Condensation commonly will be found on the lower surface of the sheathing of a roof deck due to the vapor movement from the living quarters into unvented spaces between a subceiling and the roof deck. In some cases water vapor from crawl spaces migrates along outside walls or other channels into these spaces, adding to the water vapor that penetrates the ceiling area. Condensation control is obtained by vents along the sides of the building and by a deck vent running perpendicular to the run of the joists. See "Good practice recommendations" for desirable vent areas needed. Well-vented loft spaces may not require a vapor barrier in zones II and III; however, in areas where condensation is a major problem, such as zone I, a good vapor barrier should be used in the ceiling. Other methods of including thermal insulation and vapor barriers are shown in figure 44. Where ventilation in loft side walls is effective and in the proper amount the center deck vent may not be necessary.

ALTERNATE SUBCEILING DETAILS

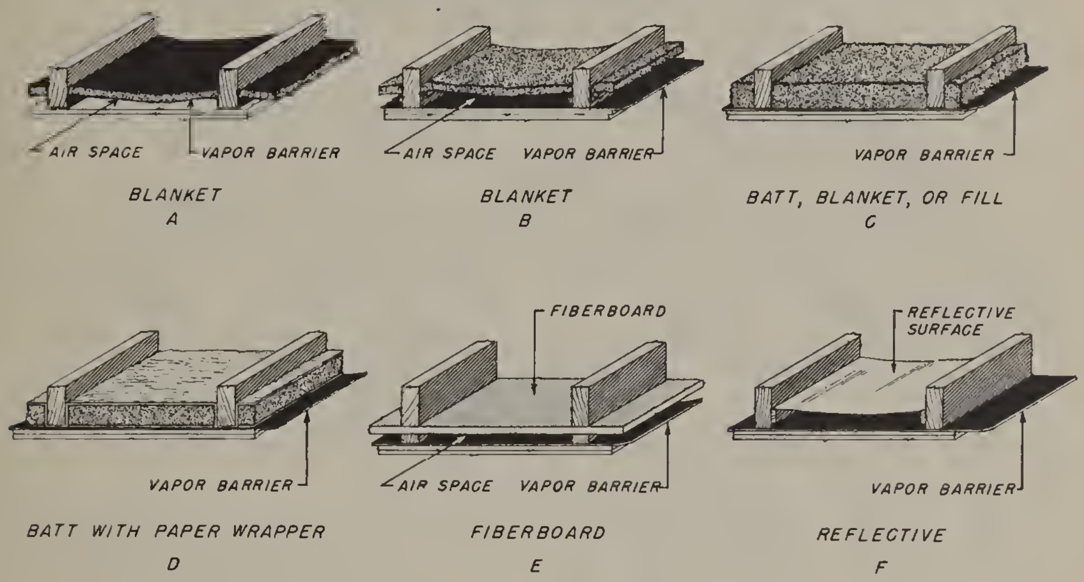

FIGURE 44.—*Alternate subceiling details.* These details are suitable for use in ceiling constructions similar to that shown in figure 43. The sketches show the use of vapor barriers for condensation control and the arrangement of several types of thermal insulation. Air spaces should be used wherever practical, and always when reflective-type insulation is employed. That shown in detail F could be surfaced two sides and the vapor barrier could be metallic-surfaced paper or metallic-surfaced gypsum board. The upper surface of the reflective surface may be impaired in time by dust collection when used in a detail such as shown in figure 43.

HIP ROOF, ENCLOSED RAFTERS

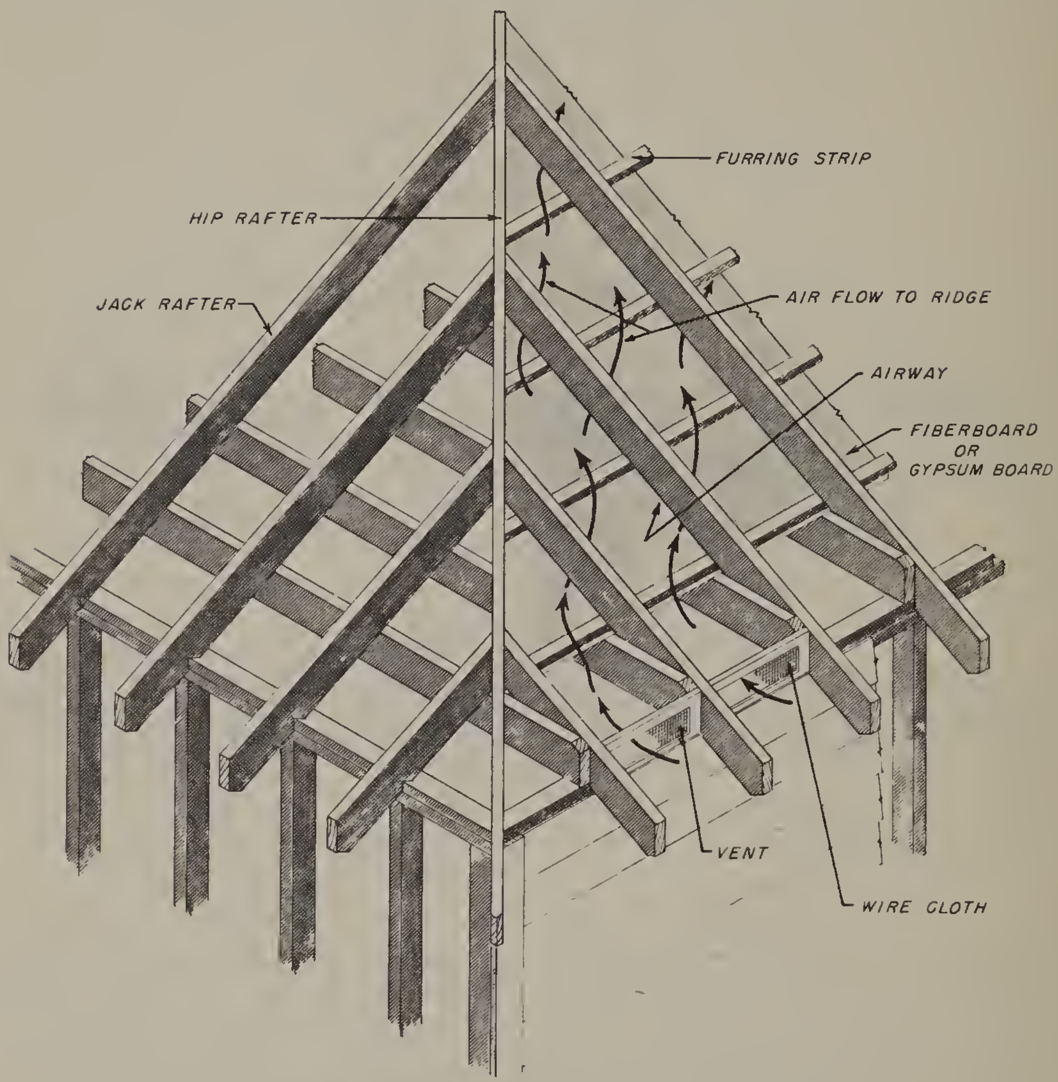

FIGURE 45.—*Hip roof, enclosed rafters.* Hip-roof construction presents a special problem when it is desired to enclose or insulate the roof because of the complete closure of the spaces between the jack rafters by the hip rafter when the insulation is applied between or on the under side of the rafters. If rooms are built into the attic they should be constructed independent of the roof structure or furred in such a way that air will not be trapped in the construction. Fiberboard is used for thermal insulation and the interior surface in this detail. An inlet for fresh air is shown below the eaves and airways throughout the roof construction. Although not shown, it is assumed that an outlet will be provided to permit the discharge of air near the ridge. Figures 41, and 46 to 49 indicate how this may be done and the sizes of openings are given in "Good practice recommendations."

MODIFIED HIP ROOF WITH VENTS

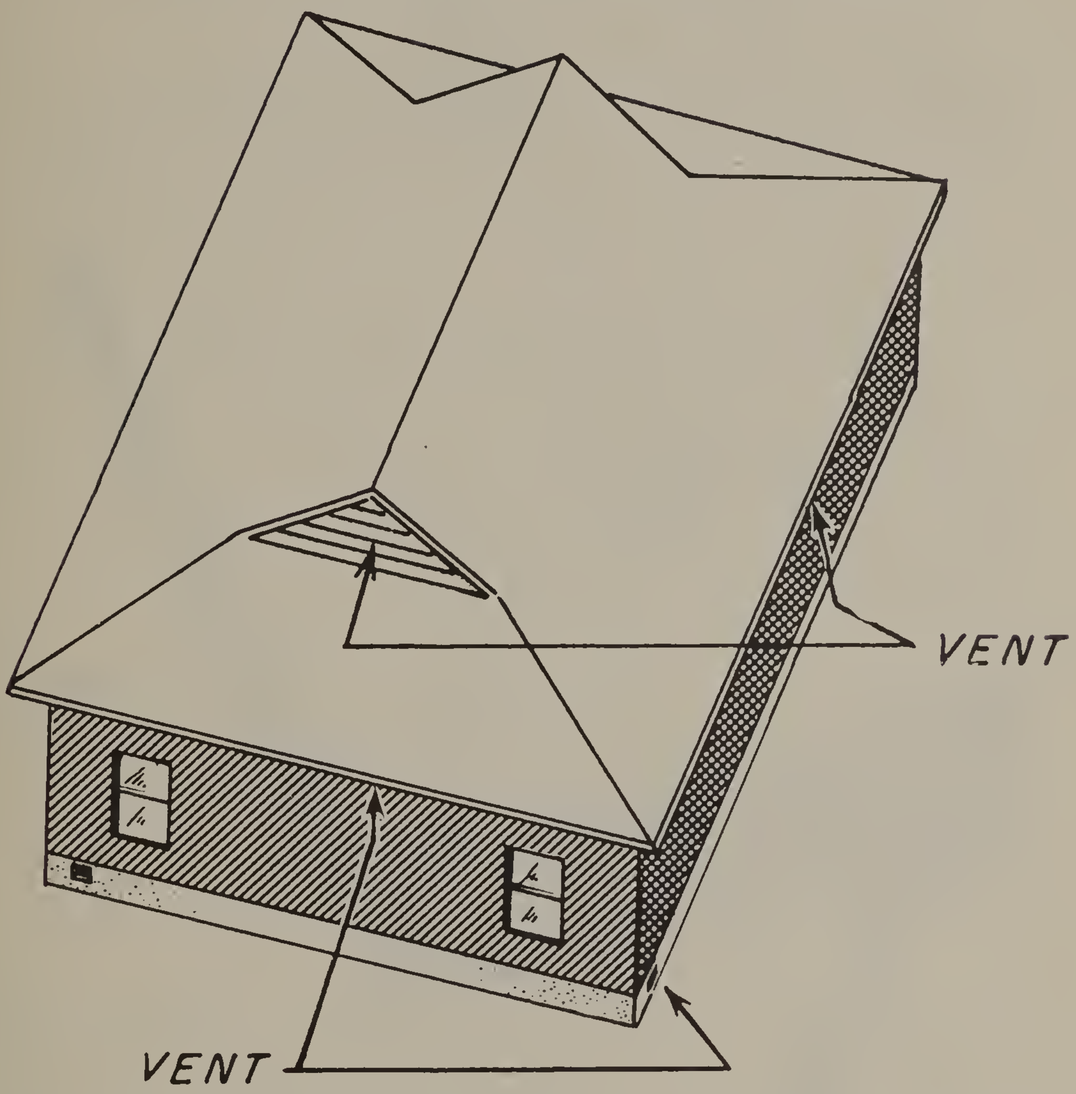

FIGURE 46.—*Modified hip roof with vents.* This type of construction is designed to provide condensation control in the form of ventilation. In addition to the vents shown in the roof, narrow continuous vents below the eaves are suggested to provide some air circulation when there is little or no wind. See "Good practice recommendations" for vent sizes, also figure 41. Crawl-space vents are also indicated in this sketch.

SPECIAL ROOF VENT FOR HIP ROOF

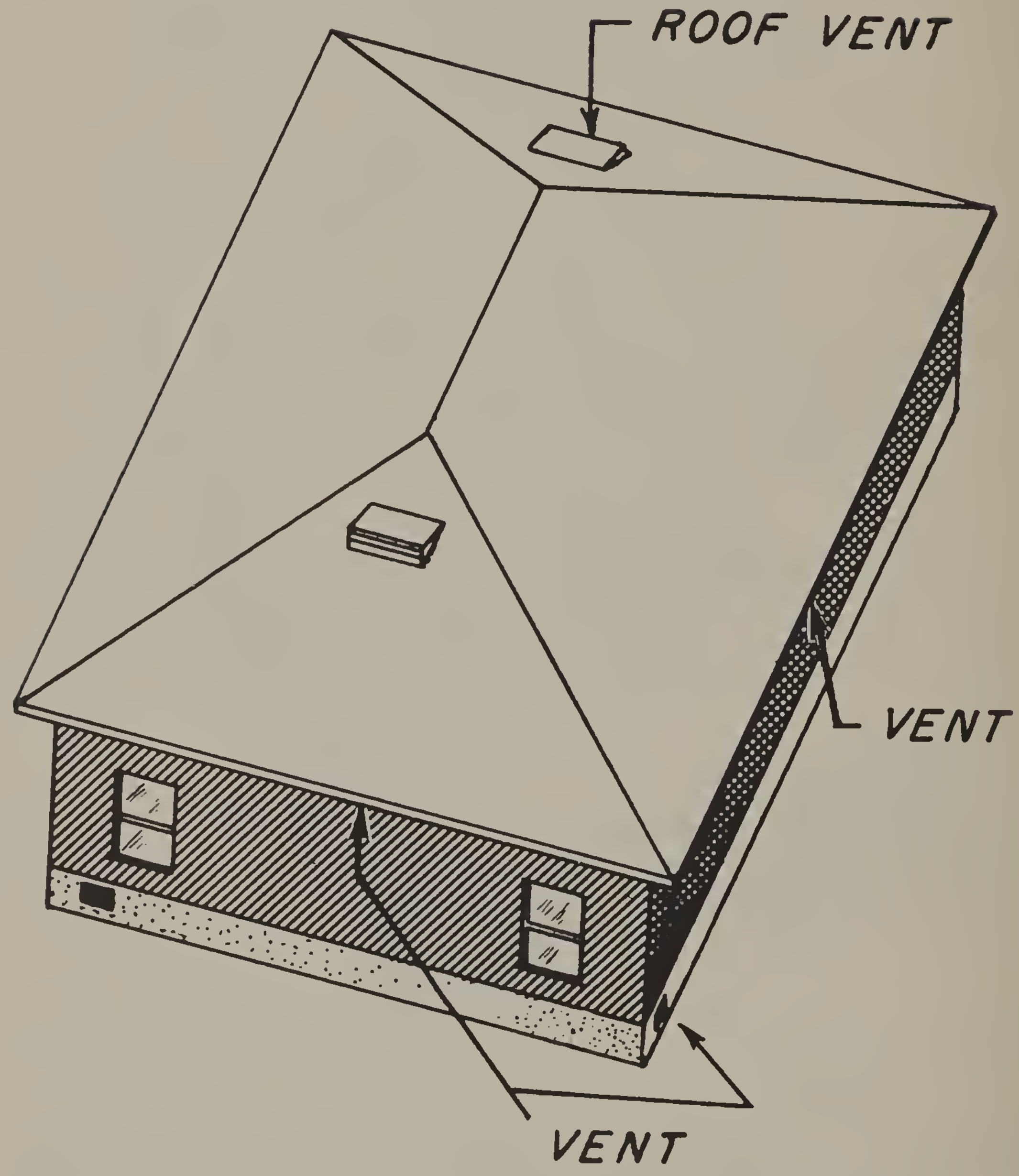

FIGURE 47.—*Special roof vent for hip roof.* This type of construction is designed to provide condensation control in the form of roof ventilation. The detail shows a small vent that should be located near the peak of the roof and with supplementary vents below the eaves. Figure 48 illustrates the general design of a roof ventilator of the type shown in this sketch. Crawl-space vents are also indicated in the foundation of the building.

LOUVER-TYPE ROOF VENTILATOR

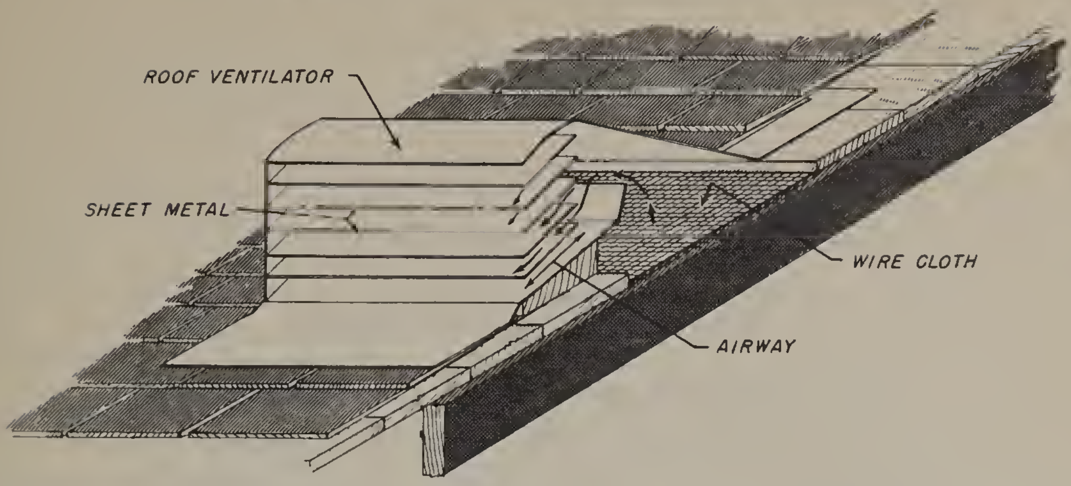

FIGURE 48.—*Louver-type roof ventilator.* Where it is desired to use a ventilator that is inconspicuous or where other types cannot be used, a low vent may be used as illustrated above. It should be carefully flashed to prevent leakage. For sizes see "Good practice recommendations."

SPECIAL ROOF VENT FOR HIP ROOF

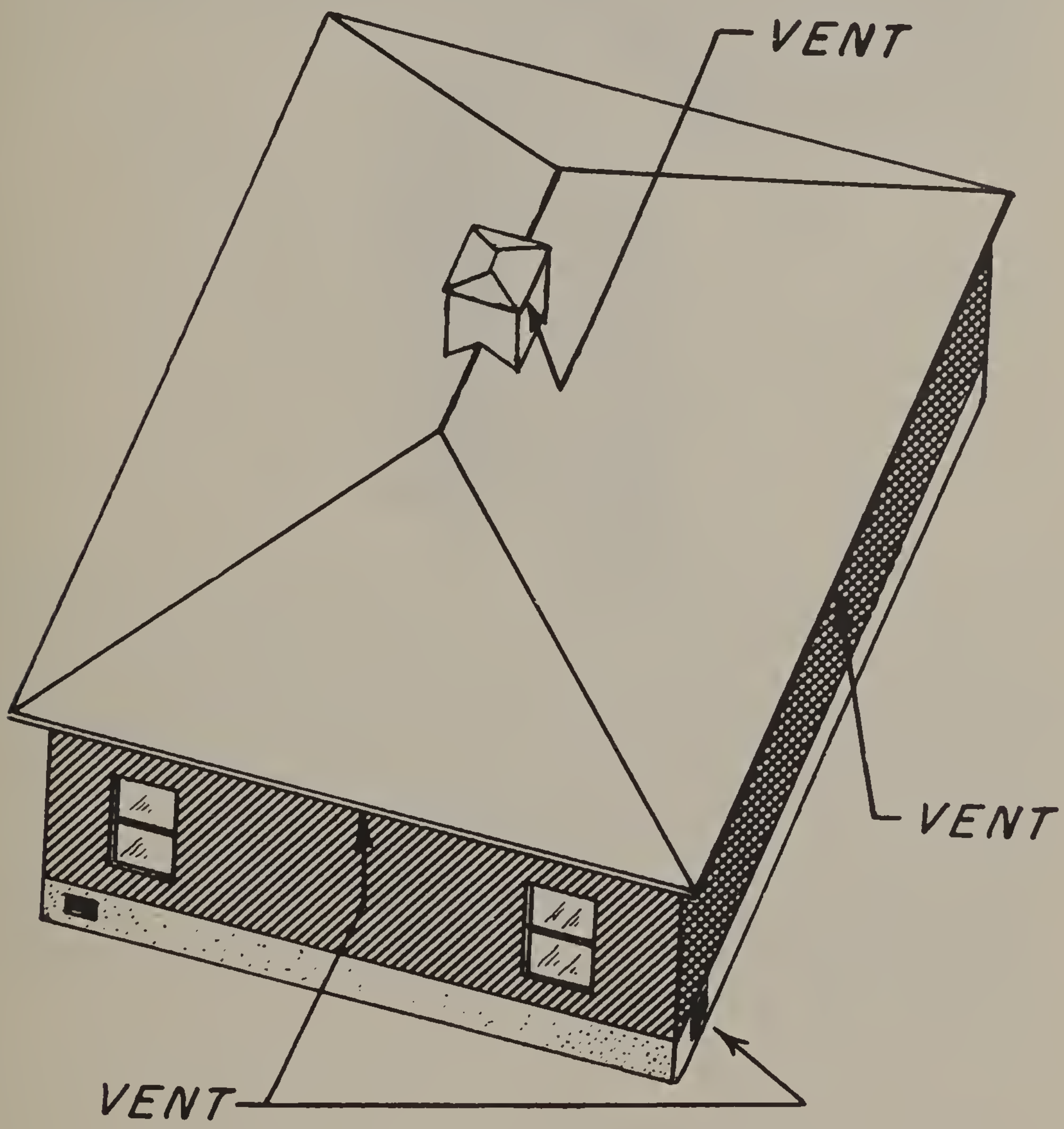

FIGURE 49.—*Special roof vent for hip roof.* This type of vent in conjunction with eave vents is arranged to provide another means of condensation control. This vent is located on the ridge of the building and supplemented by vents in the eaves. Its construction is similar to that shown in figure 43 and its net area can be obtained from "Good Practice Recommendations." The location of crawl space vents near the corners of the building is shown.

SNOW AND ICE DAMS

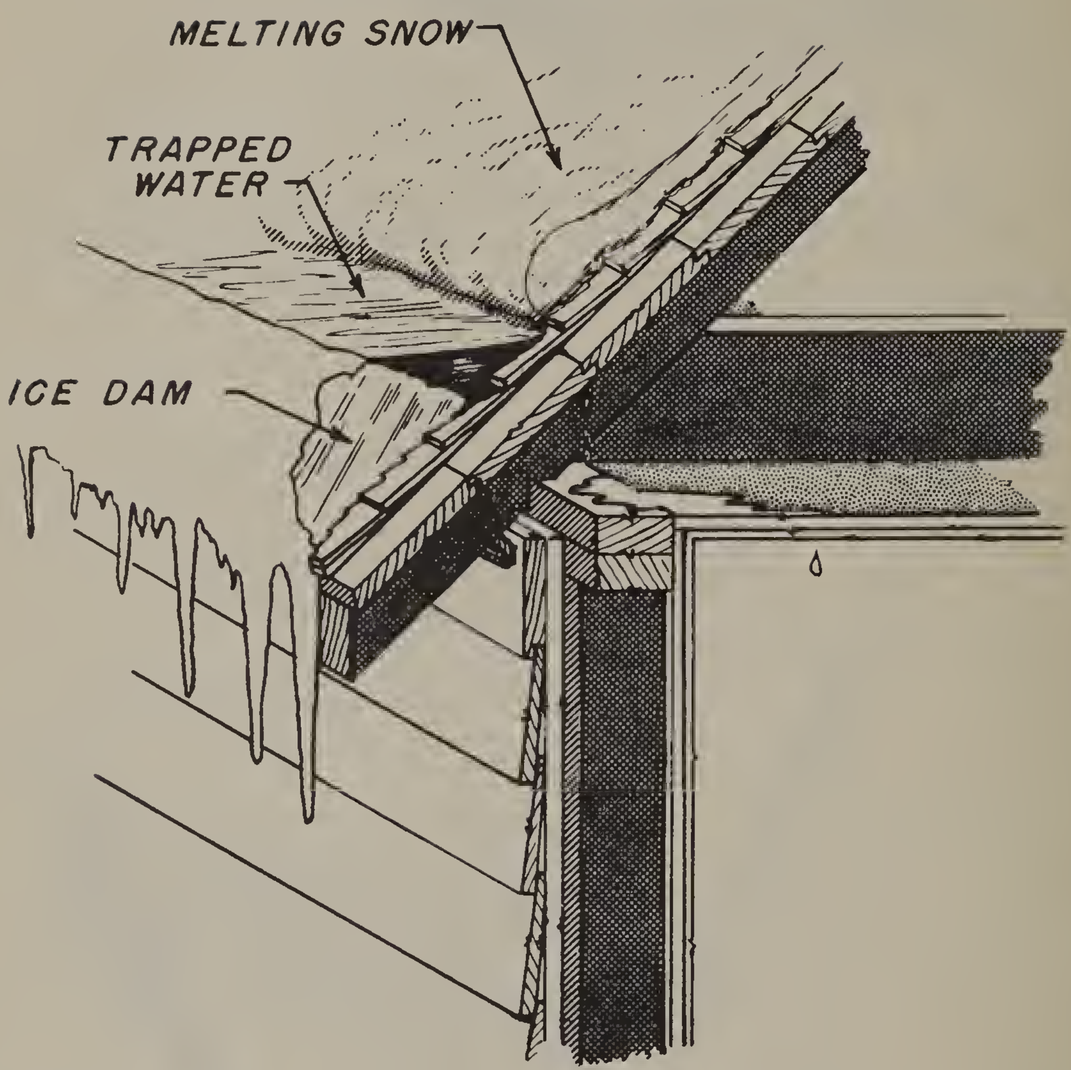

FIGURE 50.—*Snow and ice dams.* Leakage of water into buildings in the Northern States (condensation zones I and II) is sometimes caused by ice dams and is often mistaken for condensation. Snow and ice dams are usually found after heavy snowfalls followed by temperatures a little below freezing when there is sufficient heat from the living quarters to cause melting along the roof surface. The water creeps down over the roof surface and, on reaching the overhang of the roof, freezes causing a ledge of ice to build up. Water reaching this ice ledge may back under and between the shingles and into the building. Corrective measures consist of a course of heavy roll roofing below the shingles reaching up beyond the wall line. (See fig. 51.)

EAVE PROTECTION, SNOW AND ICE DAMS

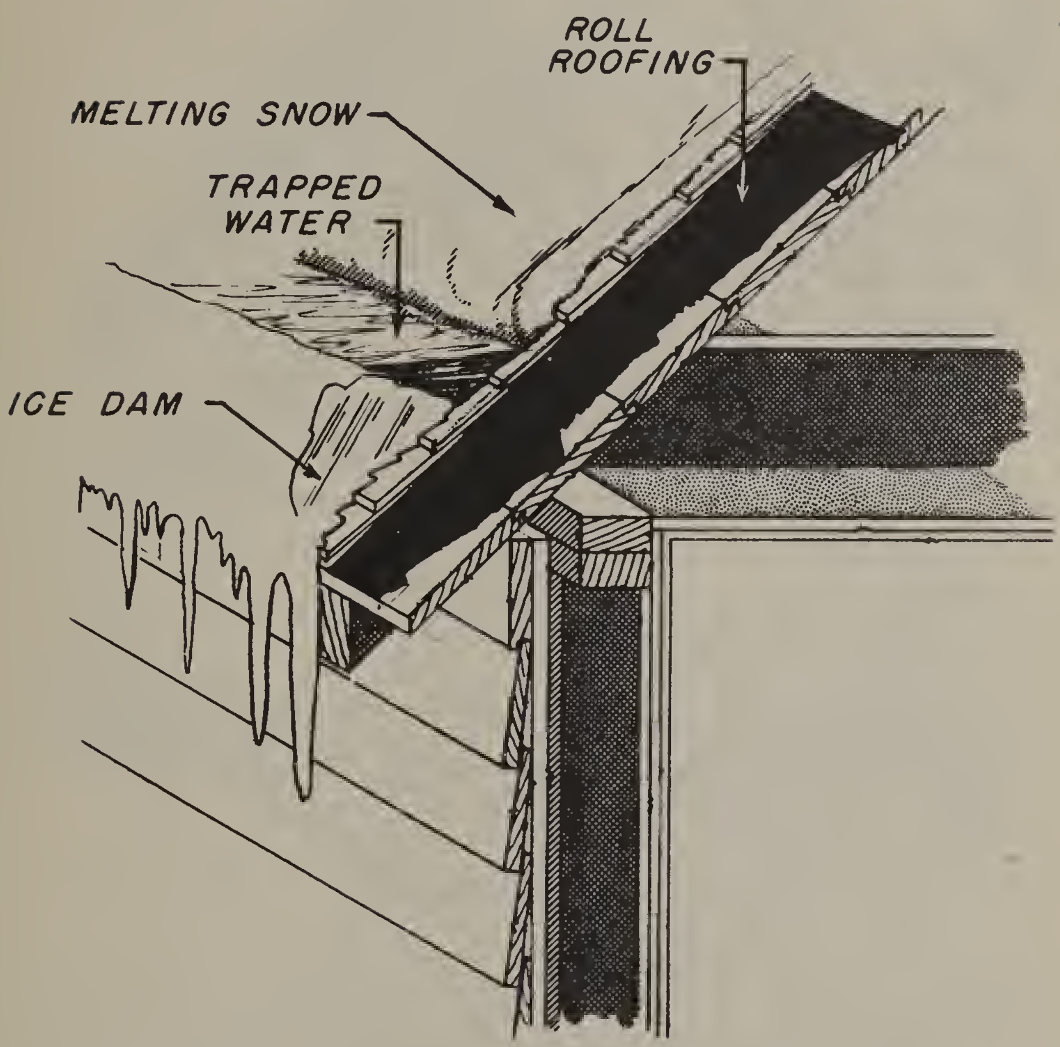

FIGURE 51.—*Eave protection, snow and ice dams.* The conditions producing snow and ice dams are indicated in figure 50. The simplest way of preventing such leakage of water is to lay a single course of heavy roofing felt over the eaves and extending upwards well above the inside line of the wall. Sheet metal could also be used as a lining material.

ICE KNOBS ATTACHED TO PROTRUDING NAILS

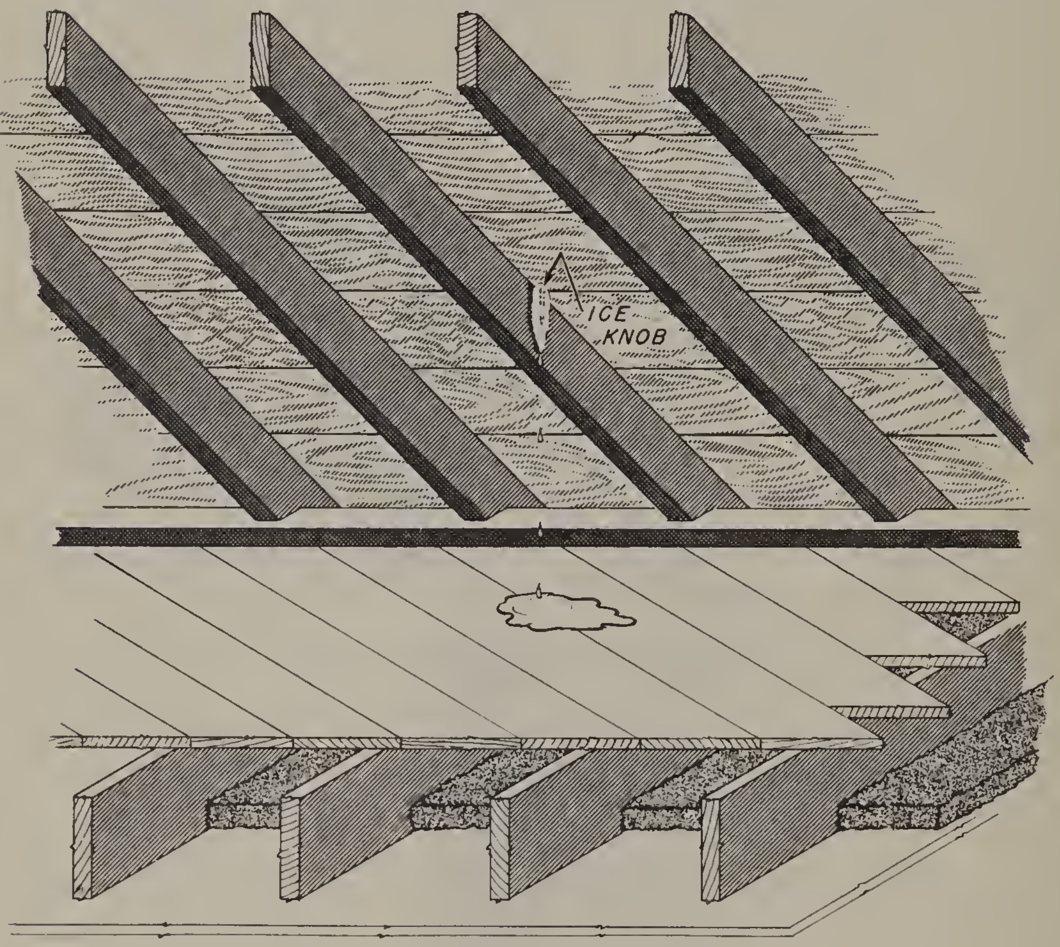

FIGURE 52.—*Ice knobs attached to protruding nails.* Frequently in the construction of a building nails are used that are longer than needed or they miss the supporting member in which driving was intended and the points project into the attic or wall. The heads of these nails sometime come close to the outside surface of the roof and since the nails are better conductors of heat than wood they become the coldest surfaces in the attic or wall and condense water. During prolonged periods of cold weather the protruding nails accumulate ice knobs that later melt and stain the ceilings below. As a safeguard against such damage, nails of this kind should be clipped off close to the wood.

OPENING INTO UNHEATED ATTIC SPACE, DETAIL NO. 1

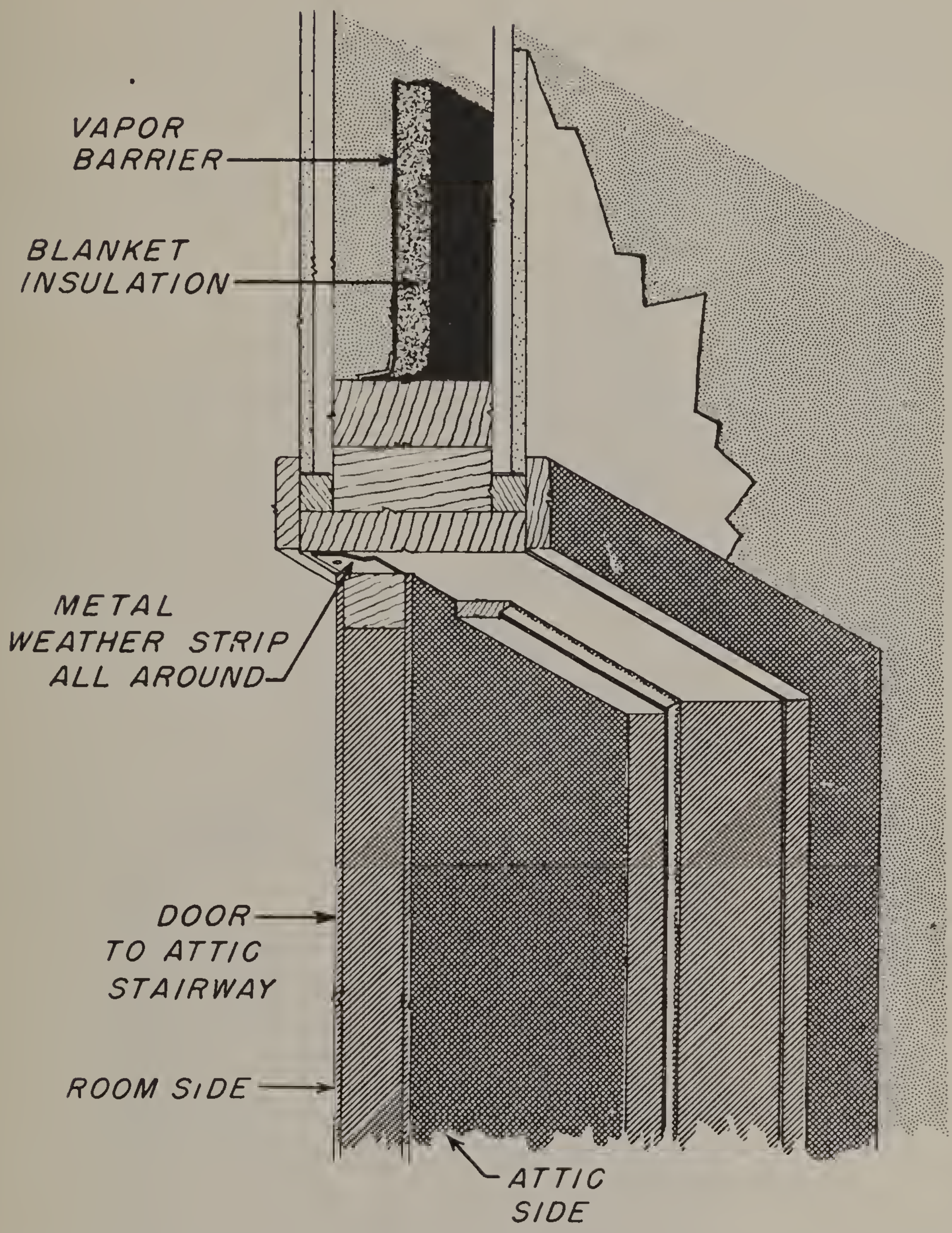

FIGURE 53.—*Opening into unheated space, detail No. 1.* Poorly fitted or warped doors and scuttles leading into unheated attic or storage spaces may admit a considerable amount of water vapor and permit unnecessary heat losses. The quantity of water vapor admitted in this way may be reduced by fitting doors to door stops carefully by the use of weather strips or other seals. Thermal insulation may be advantageously added to the backs of doors adjacent to cold spaces.

OPENING INTO UNHEATED ATTIC SPACE, DETAIL NO. 2

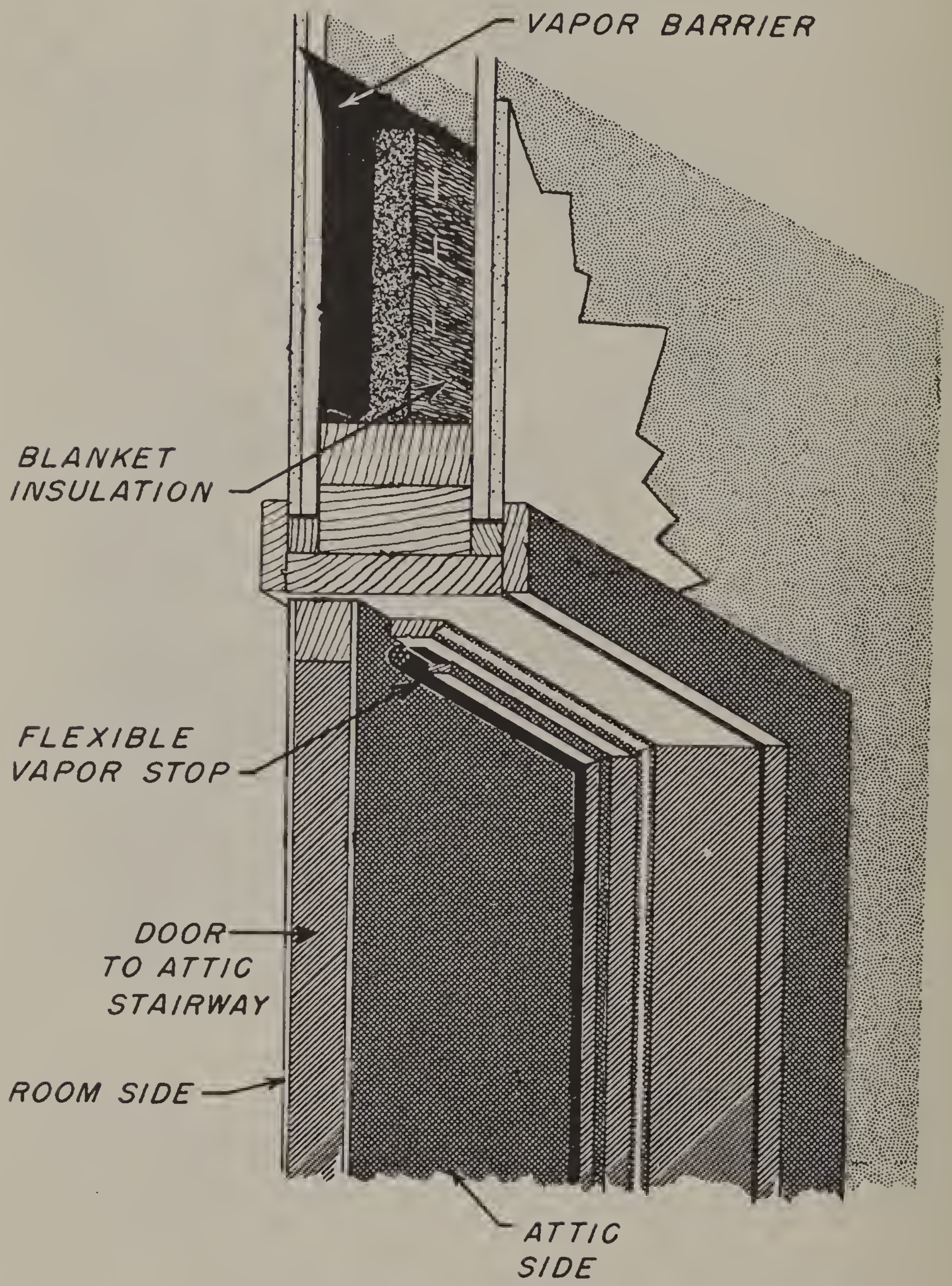

FIGURE 54.—*Opening into unheated attic space, detail No. 2.* Another method for making tight seals of attic doors is to attach flexible vapor stops, as shown.

OPENING INTO UNHEATED ATTIC SPACE, DETAIL NO. 3

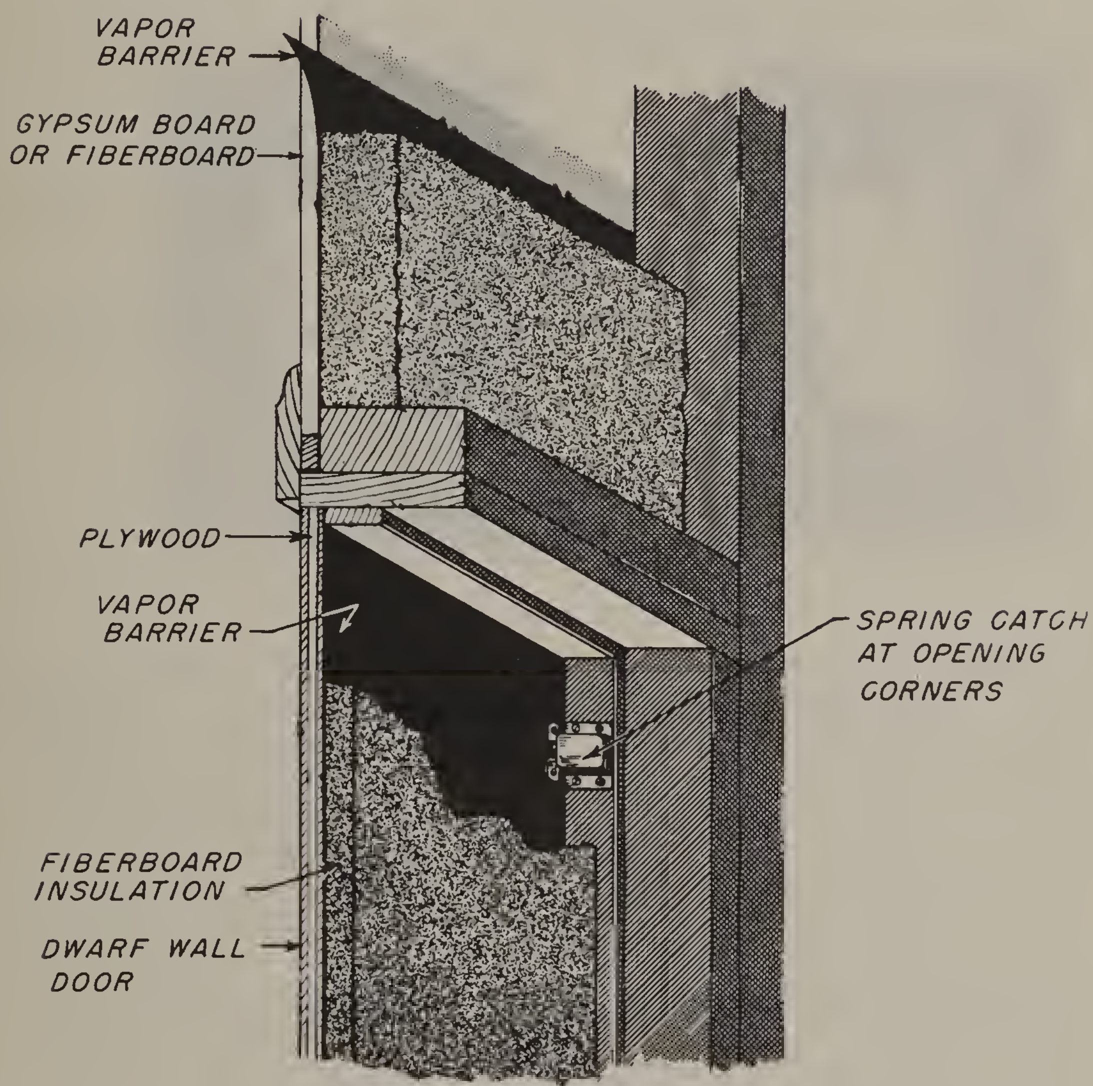

FIGURE 55.—*Opening into unheated attic space, detail No. 3.* Thin doors that are inclined to warp should be held against stops by mechanical or spring catches so placed as to draw them up against the stops. Scuttles in the ceiling should be closed tightly, in like manner.

FITTING VAPOR BARRIER AROUND ELECTRIC WIRING OUTLET BOX

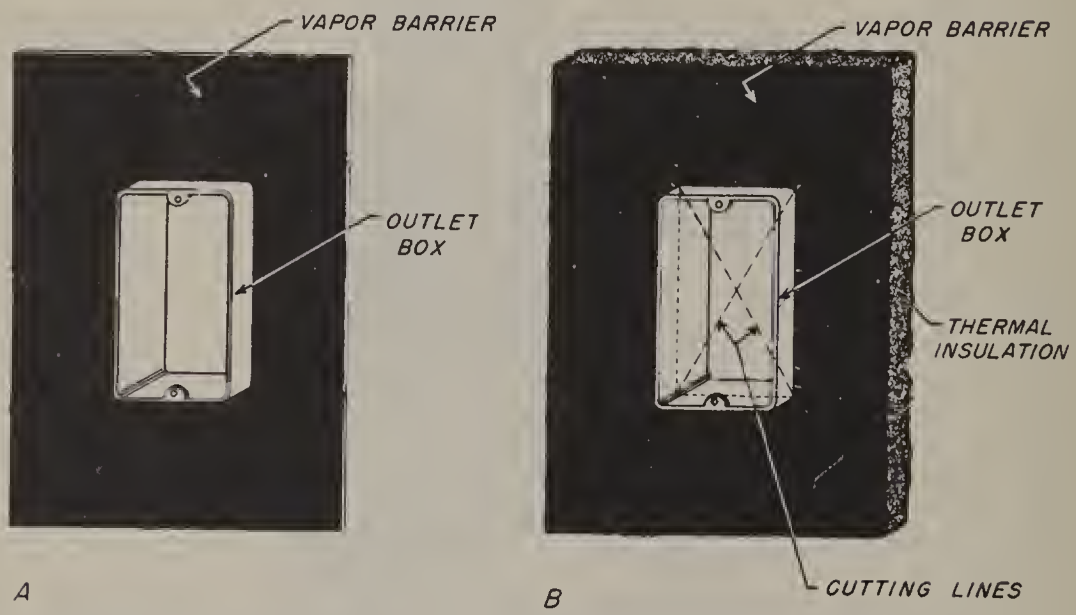

FIGURE 56.—*Fitting vapor barrier around electric wiring outlet box.* Vapor barriers should be well fitted around electric switch and outlet boxes to prevent water vapor leakage into the wall. The paper should be stapled to the wood structure and laid over the outlet box, and in this position can be broken or cut by striking it above the edge of the box with a hammer so as to crush or break the paper (A). It could also be cut along the edge of the box with a sharp knife. The barrier should be pushed over the edge of the box without tearing it. No more openings should be made in the outlet box by the electrician than are actually needed thus preventing vapor flow through the box itself. Blanket insulation with a vapor barrier attached may be cut diagonally over the box, most of the fiber between the covers should be removed and the corners tucked down at the sides of the box (B).

APPENDIX 1

Methods for Computing Recommended Amounts of Insulation

The United States covers a wide range of climatic conditions from the severe winters in the North to mild and semitropical conditions in the South. It is obvious that economic considerations and comfort should control the amount of thermal insulation needed in any installation. The thermal properties of most building materials are known, and the coefficient of transmission, or "U" value, for most combinations of construction and insulation can be calculated, (*4*, *7*, *23*), or obtained from manufacturers of thermal insulation. The "U" value represents the over-all coefficient of heat transmission and is the amount of heat expressed in British thermal units transmitted in 1 hour through 1 square foot of surface per 1° F. difference in temperature between the inside and outside air. Figure 57 indicates the outside design temperatures by zones. Table 2 gives room-surface temperatures and corresponding "U" values for typical outside design temperatures. The minimum room-surface temperature of exterior walls should not be below 59° F. while the optimum condition for buildings constructed with walls that provide more comfortable conditions has been variously stated to be between 63° and 68° F. (Wall-surface temperatures are given for 63°, 65°, and 68° F. as information.) Floor-surface temperatures should not be less than 60° F.

TABLE 2.—*Room-surface temperatures and corresponding "U" values for outdoor design temperatures*

Outdoor design temperature (° F.) [1]	Room-surface temperatures				
	Walls				Floors
	59° F.	63° F.	65° F.	68° F.	60° F.[2]
+30	0.45	0.30	0.20	0.10	0.60
+20	.36	.24	.16	.08	.48
+10	.30	.20	.13	.07	.40
0	.26	.17	.11	.06	.34
−10	.23	.15	.10		.30
−20	.20	.13	.09		.27
−30	.18	.12	.08		.24
−40	.16	.11	.07		.22

[1] Outdoor design temperature for any locality can be obtained by reference to the local utility or fuel dealer.
[2] For floors over unheated, well-ventilated spaces.

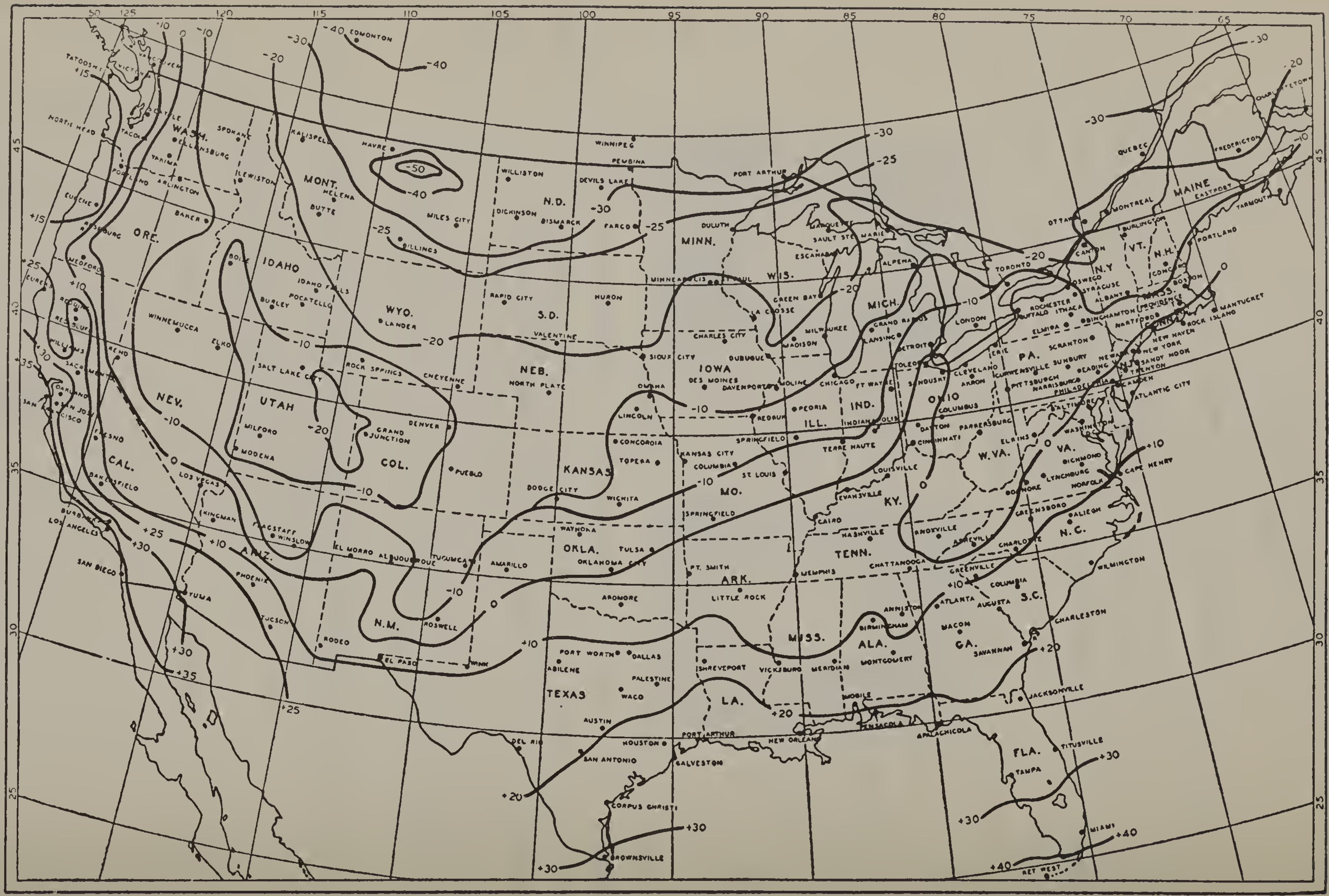

FIGURE 57.—*Average outside design temperature zones of the United States* (8). Reproduced by permission, from 1948 Heating, Ventilating Air Conditioning Guide (23)

Although the map in figure 57 shows lines of separation between zones, it is obvious that weather is variable and lines cannot be more than a general guide. Further, differences of elevation within a zone may produce lower temperatures than the surrounding areas. In other words, some judgment should be exercised in the use of this zoning map.

It is expected that conservation of fuel resources will become of greater importance as time goes on and it may be desirable to decrease the numerical value of the coefficients of heat transmission in the interest of present and future fuel economy. The use of more insulation than needed to produce a 59° F. room-surface temperature is economically sound and should be more so if fuel prices increase.

APPENDIX 2

Literature Cited

1. Betts, B. F.
   1936. Thermal insulation of houses. Better Homes in America, Purdue Univ. Bul. 4, 30 pp., illus.
2. Britton, R. R.
   1948. Condensation in walls and roofs . . . Housing and Home Finance Agency Tech. Paper 8, 21 pp., illus.
3. ———
   1948. Crawl spaces . . . Housing and Home Finance Agency Tech. Bul. 2: pp. 17–39, illus.
4. Browne, F. L.
   1927. Some causes of blistering and peeling of paint of house siding. Amer. Paint and Varnish Mfrs. Assoc., Sci. Sect. Cir. 317, pp. 480–486.
5. Close, P. D.
   1946. Building insulation . . . Ed. 3, 372 pp., illus. Amer. Tech. Soc., Chicago.
6. Diller, J. D.
   1946. Decay a hazard in basementless houses on wet sites: protection of the substructure timbers from excessive moisture by the use of an asphalt roll roofing as a soil cover. Amer. Builder 68 (7): 92, 122, 124, illus.
7. Federal Housing Administration.
   1947. Calculation of building section heat transmission coefficients. Fed. Housing Admin. Tech. Cir. 7 rev., 51 pp., illus.
8. Garver, H. L.
   1948. Your farmhouse; insulation and weatherproofing. U. S. Dept. Agric. Misc. Pub. 633, 16 pp., illus.
9. Heating, Ventilating, Air Conditioning Guide.
   1948. Chap. 5. Fundamentals of heat transfer. Pp. 97–110.
   Chap. 6. Heat transmission coefficients of buildings materials. Pp. 111–139, illus.
   Ed. 26, 1280 pp., illus. Amer. Soc. Heating and Ventilating Engin., New York.
10. Housing and Home Finance Agency.
    1948. Attic condensation in tightly built houses. Housing and Home Finance Agency Tech. Bul. 6: 29–46.
11. ———
    1948. Water penetration and vapor permeability of sheet materials as related to condensation control in dwelling construction. Housing and Home Finance Agency Tech. Bul. 5: pp. 33–37.
12. Lendrum, J. T., Konzo, S., Kratz, A. P., and Harris, W. S.
    1946. Insulation in the home. Ill. Univ. Small Homes Council, F 6.0, 8 pp., illus.
13. Purdue University.
    1936. Dry cellars. Better Homes in America, Purdue Univ. Bul. V. 1, No. 12, 15 pp., illus.

14. Queer, E. R., and McLaughlin, E. R.
1948. What to do about condensation. Housing and Home Finance Agency Tech. Bul. 4 : pp. 19–27, illus.
15. Rowley, F. B.
1947. Moisture condensation. Ill. Univ. Small Homes Council, F 6.2, 8 pp., illus.
16. Rowley, F. B., and Jordan, R. C.
1945. Economics of insulation. Minn. Univ. Inst. Tech. Engin. Expt. Sta. Bul. 23, 69 pp., illus.
17. Rowley, F. B., Algren, A. B., and Lund, C. E.
1941. Condensation of moisture and its relation to building construction. Minn. Univ. Engin. Expt. Sta. Bul. 18, 69 pp., illus.
18. Rowley, F. B., and Algren, A. B.
1937. Thermal conductivity of building materials. Minn. Univ. Engin. Expt. Sta. Bul. 12, 134 pp., illus.
19. Shuman, L.
1948. Insulation, where and how much. Housing and Home Finance Agency Tech. Bul. 3 : pp. 1–15, illus.
20. ———
1947. Insulation of concrete floors in dwellings. Housing and Home Finance Agency Tech. Bul. 1 : pp. 18–28, illus.
21. Teesdale, L. V.
1947. Remedial measures for building construction. U. S. Dept. Agr., Forest Serv., Forest Prod. Lab. Report No. R 1710, 27 pp., illus.
22. ———
1941. Condensation problems in modern buildings. U. S. Dept. Agr., Forest Prod. Lab. Report No. R 1196, 9 pp., illus.
23. ———
1942. Comparative resistance to vapor transmission of various building materials. ASHVE Jour. Sec., Heating, Piping, and Air Conditioning, 14 (12) : pp. 736–742, illus.
24. U. S. Department of Commerce, National Bureau of Standards.
1943. Heat-transfer properties of six wood frame walls sponsored by the National Lumber Manufacturers Association. Natl. Bur. Standards Tech. Rpt. Bldg. Mater. for Use in Design of Low-cost Housing TRBM 40, 22 pp., illus.

GLOSSARY OF CONDENSATION AND HOUSING TERMS

Basementless house. A house supported on a platform of concrete resting on the ground or a house supported on piers or a masonry foundation varying from a few inches to 4 feet above the ground surface and not of sufficient height for a person to walk in an erect posture.

Batt insulation. A fibrous insulating material preformed to a definite thickness and width and supplied in short lengths up to 48 inches with or without sheet materials to assist in maintaining shape or handling. Batts are usually made to fit between studs spaced 16 and 24 inches apart.

Blanket insulation. An insulating blanket is a fibrous insulating material preformed or assembled to provide a definite thickness and width and available in long lengths. Blankets are usually provided with edges especially formed to effect continuous attachment in order to maintain its position as installed. Blanket insulation is supplied (1) without wrappers, (2) completely enclosed in a vapor resistant envelope, (3) one side with a vapor barrier and a light perforated paper on the cold side, or (4) with the insulation mounted on a vapor barrier without a cover on the cold side.

Breathing paper. A building paper capable of preventing air infiltration, having strength when dry or wet for handling and service, and permitting the transfer of at least 5 grains of water vapor per square foot, per hour, per inch of mercury differential when tested by a dry method. A paper used in conjunction with blanket or batt type insulation on the cold side having a water vapor transmission of at least 5 grains of water vapor per square foot, per hour, per inch of mercury when tested by a dry method.

Building paper. A paper capable of preventing air infiltration or dust movement and having satisfactory strength for handling and service. It should be of such construction and composition that it is not readily wet by water but may permit the passage of water vapor.

Condensation. Free water, frost, or ice extracted from the atmosphere and deposited on any cold surface.

Conductivity. The amount of heat expressed in British thermal units transmitted in 1 hour through 1 square foot of homogeneous material 1 inch thick, for each degree temperature (Fahrenheit) difference between the two surfaces of the material. (See "k".)

Conductance. The amount of heat expressed in British thermal units transmitted in 1 hour from surface to surface of 1 square foot of material or combination of materials for each degree temperature difference between the two surfaces.

Convection. Circulating currents produced by changes in the specific gravity of air or a fluid from contact with warm or cold surfaces and in so doing effecting a transfer of heat.

Crawl space. A shallow space below the living quarters of a house. It is generally not excavated or paved and is often enclosed for appearance by a skirting or facing material.

Dew point. The temperature at which the water vapor in space becomes saturated and can hold no more moisture. Water vapor cooled below the dew point appears in the atmosphere as fog and on surfaces as dew or frost.

Durable wood. The heartwood of a species of wood naturally resistant to decay, such as redwood, southern cypress, white oak, or wood of a nondurable species treated with a wood preservative.

Fiberboard, rigid. A low-density board made from vegetable fibers (wood, sugarcane, or corn) usually formed by a felting process, dried and usually pressed to thicknesses of ½ and 25/32 inch. Usual sizes and uses are: wall sheathing, 2 by 8 feet, 4 by 8 feet and larger, dry wall finish, 4 by 8 feet and larger; plaster lath 16 inches by 4 feet. It usually has fair insulating properties.

Fill insulation. A thermal insulating material having such characteristics that it may be poured or blown into open spaces in building construction. In general, it is granular or composed of small detached clusters of fiber.

Fire stop. A blocking or closure of an opening so arranged to prevent the rapid spread of fire in wall construction.

Glass wool. See mineral wool.

Humidifier. A device designed to discharge water vapor into a confined space for the purpose of increasing or maintaining the relative humidity in the enclosure.

k. The value "k" is used to indicate the thermal insulating value of a material. It is expressed as British thermal units (B. t. u.) and is the amount of heat that will pass through 1 square foot of the material, 1 inch thick, in 1 hour when the temperature difference between the surfaces of the material is 1° F. The lower this value, the better the material is for insulation.

Mineral wool. A fibrous material made by blowing molten limestone rock, blast furnace slag, or glass into fine filaments or fibers.

Nodulated. A term applied to mineral wool products wherein the fibers are combined in small clusters of such size that they may be poured or blown into spaces to be insulated.

Organic fibers. Fibers of vegetable origin. Usually obtained by processing wood, sugarcane, cotton, and the like.

Plywood. A piece of wood made of three or more layers of veneer joined with glue and usually laid with the grain of adjoining plies at right angles. An odd number of plies are used to secure balanced construction.

R. Resistance of a substance or assembly to heat transfer—the reciprocal of total conductance.

Radiation. Heat transmitted from one object to another some distance away by wave motion and not dependent on the presence of matter for its transmission.

Reflective insulation. Sheet material with one or both surfaces of comparatively low heat emissivity which when used in building construction so that the surfaces face air spaces reduces the radiation across the air space.

Relative humidity. The amount of water vapor expressed as a percentage of the maximum quantity that could be present in the atmosphere at a given temperature. (The actual amount of water vapor that can be held in space increases with the temperature.)

Rock wool. See mineral wool.

Roll roofing. Roofing material composed of fiber and saturated with asphalt supplied in rolls containing 108 square feet in 36-inch widths. It is generally furnished in weights of 55 to 90 pounds per roll.

Sheathing paper. A paper placed between the sheathing boards, and the siding, brick, or other exterior surfacing material for the purpose of preventing the infiltration of air and driven rain into the wall section. It should be sufficiently permeable to water vapor to permit the passage of at least 5 grains of water vapor per square foot per hour, per inch of mercury when tested by a dry method.

Slag wool. See mineral wool.

Small, tight dwelling. A small, tightly constructed dwelling is considered to be one which has less than 1,500 cubic feet of volume per intended occupant, has no positive means of ventilation of the interior, and which has one or more of the following conditions: (1) storm sash or double glazing; (2) weather stripping; (3) materials that are highly resistant (less than 5 grains per square foot per hour under a pressure of 1 inch of mercury) to the passage of vapor on the cold side of the wall.

Thermal insulation. A low-density material from natural or manufactured sources capable of restricting the flow of heat from a warm to a cool zone; or a reflective metal or metallic surface and adjacent air space so arranged that outward bound heat waves are reflected back into the heated space.

Treated wood. Wood treated with chemicals that, for a reasonable length of time, prevent the action of wood-destroying fungi, borers, and similar destructive life.

U. Over-all heat transmission coefficient; the amount of heat expressed in British thermal units transmitted in 1 hour through 1 square foot of a building section for each degree temperature difference between air on the inside and air on the outside of the building section.

Vapor barrier. A membrane, aluminum paint, oil paint film, metallic sheet, rubber base, or other material capable of preventing or effectively restricting the movement of water vapor from a zone of high vapor pressure to one of lesser vapor pressure and permitting not more than 1 grain of water vapor to pass through 1 square foot in 1 hour, when the vapor pressure differential is 1 inch of mercury when tested by a dry method. A vapor barrier should be installed with closely contacting joints, free from tears or breaks and so as to have an average vapor transmission less than 1.25 grains per square foot, per hour, per inch of mercury pressure differential. Areas for inspection purposes should not be less than 60 square feet.

Vapor permeability. The property of a material that allows the passage of water vapor.

Vapor, water. Water vapor is an invisible gas present in varying amounts in the atmosphere. There is a maximum amount that can be held at a given temperature.

Ventilation. The replacement, by outside air, of the air within the building or a part thereof.

Vermiculite. A form of granulated mica which has been expanded by rapid heating. The small pieces are enlarged several times by the expansion of steam produced from water held between the surfaces of the mica flakes.

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